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PESTICIDES RESEARCH AND MONITORING ANNUAL REPORT (1987-1988)

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EXECUTIVE SUMMARY

This is the second annual report of Environment Canada's pesticides program. It summarizes the results of projects undertaken during 1987-1988 by the department's regional and district offices, research institutes and centres, branches and services. The report is organized into six sections based on the location where each project was conducted. Also included in the report are discussion documents summarizing the environmental effects of five pesticides: oxyfluorfen, pentachlorophenol, triadimefon, metsulfuron-methyl and propiconazole. An index is included at the end to enable readers to easily identify studies related to a particular topic.

The following is a brief summary of the projects undertaken in each of the five regions.

The Atlantic region focussed on identifying the effects of fenitrothion spraying on forest songbirds, pollinators and aquatic insects, and on developing more sensitive techniques to measure the chemical's effects on birds. Fenitrothion has been sprayed aerially since 1966 to control insect pests such as the spruce budworm and hemlock looper in conifer forests in the region. The Atmospheric Environment Service was involved in this region on projects designed to optimize the deposition of aerially applied pesticides on the forest canopy and to reduce spray drift. The region also concentrated on monitoring for the presence of organotin chemicals in the environment and in assessing their effects on marine shellfish. Organotin chemicals are present as antifouling agents in marine paints used on boat hulls; the chemicals were also used as preservatives in aquaculture systems and in lobster traps. Quality of the drinking water in this region was also monitored. In addition, the groundwater beneath potato fields in Prince Edward Island was monitored for aldicarb. This pesticide, used to control insect pests of potatoes, has been observed to leach through the soil into the groundwater.

In the Quebec region, a survey was conducted to compare the socio-economic background of three groups of fruit and vegetable farmers and their attitude towards the use of pesticides. The groups differed in their methods of controlling pests on their farms -- IPM farmers integrate their use of pesticides with other pest management practices; conventional farmers use pesticides without regard for pest population levels; biological control farmers use no pesticides at all. In the area of pesticide monitoring, the region studied the highly agricultural Yamaska and Saint-François river basins for the presence of several pesticides. In this connection, the National Water Research Institute in Burlington studied the community structure of sediment organisms and examined fish

tissues in the Yamaska to assess possible degradation caused by pesticides. The region was also involved in the development and use of models to predict the amount of pesticides that could potentially move out from agricultural areas into surrounding waterbodies or into groundwater.

In the Ontario region, the Atmospheric Environment Service was involved in studying the transport of toxaphene from the southern United States to the Great Lakes. The National Water Research Institute in Burlington assessed the effects of low levels of pesticides to freshwater organisms.

The Western and Northern region carried out projects in Manitoba to determine the presence of pesticides in surface water in the Stephenfield reservoir. In Saskatchewan, projects were aimed at determining the presence of pesticides in the atmosphere around agricultural areas and in the groundwater at Outlook. In addition, several projects were undertaken in this region to determine the toxic effects of pesticides on aquatic insects and on birds such as the burrowing owl, loggerhead shrikes, prairie songbirds, and mallard ducklings.

The pesticides studied were used intensively by farmers to control severe grasshopper outbreaks over the last four years. The region also initiated a critical review of the database of three pesticides viz MCPA, carbaryl and creosote. In addition, the Water Quality Branch in this region was involved in routine monitoring to determine the quality of drinking water in the prairies.

The Pacific and Yukon region concentrated on assessing the presence of chlorophenol and dioxin in the environment around wood treatment facilities and pulp mills and in determining the levels of organotins in salmon farms and marinas. The region also assessed the extent of groundwater contamination by pesticides in Abbotsford and Osoyoos and evaluated the toxicity of hexazinone to salmon. Hexazinone is used for brush control in forests.

Readers are encouraged to peruse the articles pertaining to their areas of interest and to contact the individual listed at the end of each article for more information.

PESTICIDES PROGRAM IN THE ATLANTIC REGION
(New Brunswick, Prince Edward Island, Newfoundland, Nova Scotia)

1. OPTIMIZATION OF SPRAY OPERATIONS BY MODEL SIMULATION - (J.J.C. Picot and D.J. Wallace)

Introduction:

Protection of forest crops by aerial spraying of pesticides is an essential component in the forest industry. The effectiveness of an aerial spray operation is determined by a number of variables including aircraft type, flight conditions, atomizer and atmospheric stability conditions.

Aerial spray operations are most effective when the droplet density (number of drops deposited per needle) is maximized and off-target drift is minimized. The dropsize range recommended in pesticides spraying is 5 to 55 μm after evaporation (Picot et al., 1987). Smaller droplets contribute significantly to off-target drift. Larger droplets yield a poor ratio of foliage surface area covered to volume of spray released. The PKBW model (Picot et al., 1987) is a numerical model which simulates the dispersion of a spray released from an aircraft over a forest canopy. The model accounts for the type of aircraft used, aircraft flight conditions, atomizer type, atmospheric turbulence, and droplet evaporation and foliage deposition.

Objectives:

The objective of this study was to use the PKBW model to optimize aerial spray application procedures typically in use in New Brunswick's spruce budworm spray program. The criteria for determining the optimal conditions were minimum percent drift and maximum drop counts collected per needle.

Methodology:

A total of 24 numerical simulation runs were performed, each representing a unique set of aerial spraying operating conditions. The drift and deposition results from the 24 simulation runs provided sufficient information to extrapolate predictions to a total of 91 unique sets of spraying conditions. The operating conditions for each of the 91 sets were chosen by varying four parameters: aircraft type, aircraft height, nozzle type (dropsize spectra) and atmospheric stability. Three sets of conditions for each of the four parameters were exploited. Aircraft type was studied by examining differences in the performance of a TBM-Avenger, an AgTruck Cessna-188 and a Bell 206 helicopter. Aircraft heights of 30, 36 and 42 metres above ground were used. The nozzles examined were a Teejet 11010, an AU4000 Micronair run at 9 000 rpm and an AU4000 Micronair run at 14 000 rpm. Finally, three different atmospheric stability classes with Monin-Obukhov lengths of -53 metres (unstable), infinity (neutral) and +53 metres (stable) provided the variation in atmospheric stability.

Results and Discussion:

Drift and deposition results from the simulation runs revealed four important points:

1. Under any operating conditions, an unstable atmosphere provided the most favourable conditions for spraying, both from the point of view of minimizing drift, and maximizing drop counts per needle.

2. The Bell 206 helicopter showed a considerable improvement over the TBM and AgTruck in minimizing drift.

3. Maintaining a low aircraft height is important in minimizing drift and increasing droplet deposition on the foliage.

4. When smaller droplets are generated, the percent drift tends to increase, but so does the number of drops per needle. Therefore, in order to achieve a specific droplet density (number of drops per needle), the application rate can be reduced when smaller droplets are used. This could lead to a net reduction in the absolute (but not percent) amount of material subject to drift. The advantage of using smaller droplets, however, is lost under stable atmospheric conditions.

The drift and deposition results obtained in this study demonstrate the potential of optimization studies of this nature. Additional simulation runs would have to be conducted to expand the scope of operating conditions (different relative humidities, windspeeds at aircraft height, etc.). The use of such information would ease the complexity of estimating drift and deposition for specific aerial spraying conditions.

References:

Picot, J.J.C., D.J. Wallace, and D.D. Kristmanson, "The PKBW Model for Prediction of Aerial Spraying Deposition and Drift", presented at the Symposium on the Aerial Application of Pesticides in Forestry, Ottawa (Oct. 20-22, 1987).

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2. LIDAR MAPPING OF AERIAL SPRAY - (R. Hoff, F. Froude, and R. Mickle)

Introduction:

Past studies, both experimental and modelling in nature, have shown that the "effective release height" of aerially-applied sprays is the most important factor in deposition of the spray to a forest canopy. Vortex behaviour from the aircraft, coupled to atmospheric stability, has been found to be a controlling factor in the "effective release height" and deposition.

Objectives:

This project is designed to develop and test a remote sensing system capable of mapping aerially-applied spray drift above forest canopies. The system will be used to establish the meteorological conditions which minimize spray drift and increase application efficacy.

Methodology:

A scanning LIDAR system was developed to map the spray cloud released from agricultural and forest spray aircraft. The Neodymium-YAG laser fires ten shots per second and scans up to 5° in elevation in six seconds in order to map the cloud. The horizontal and vertical resolution of the system are approximately 1.5 m allowing good visualization of the two vortices from even small aircraft such as the Cessna 288. Data are processed to give a visual picture of the spray cloud as it drifts and the backscattered light signal is scaled to represent the percentage of spray aloft as a function of time after release.

Results and Discussion:

The technique was applied to two aircraft types, two nozzle configurations, and three different atmospheric stability regimes in a one-week study over the New Brunswick spruce forest in August 1987. The combination of spray parameters has shown interesting effects such as differential deposition of the upwind and downwind spray vortices, vortex bounce in stable atmospheric regimes, and complete decoupling of the vortices from the canopy in some early morning stable cases. Cases were observed with vertical drift to a height of 90 m (with the spray height of 30 m) within 30 m after aircraft passage. These results were shown at the ACAFA Symposium on Aerial Applications of Pesticides in Forestry in Ottawa (1987) and a journal publication has been submitted.

The results from the experimental studies will be coupled to modelling efforts in understanding vortex behaviour. Recommendations regarding application procedures in various stability regimes are being considered.

References:

R.E. Mickle, "An Evaluation of Models Presented in Session V", ACAFA Symposium on Aerial Applications of Pesticides in Forestry, Ottawa, Ontario (Oct., 1987).

R.M. Hoff, R.E. Mickle, and F.A. Froude, "A Rapid Acquisition LIDAR for Measurement of Aircraft Spray Drift", 14th International Laser Radar Conference, Innichen-San Candido, Italy (June, 1988).

R.M. Hoff, R.E. Mickle, and F.A. Froude, "A Rapid Aquisition LIDAR System for Aerial Spray Diagnostics", submitted for journal publication.

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3. ASSESSMENT OF THE VARIABILITY OF FENITROTHION DEPOSIT DURING OPERATIONAL FOREST SPRAYING - (W. Pierce and W. Ernst)

Introduction:

In the recent past, there have been annual spray programs in Newfoundland and Labrador against the spruce budworm (*Choristoneura fumiferana*) and hemlock looper (*Lambdina fiscellaria fiscellaria*). Environmental impact investigations have suggested that non-target effects of these spray programs may be exaggerated compared with similar programs in other jurisdictions. Such variable effects could be related to real differences in the sensitivities of the receiving environment to the pesticide treatments. It has also hypothesized that variable exposure sites could account for measured differences in non-target effects.

Objectives:

Accordingly, as part of the 1987 Newfoundland and Labrador hemlock looper spray program, a study was undertaken to determine the variability of spray deposit within spray blocks between spray blocks and the frequency of higher than acceptable deposit.

Methodology:

Within each of six operational spray blocks which were treated with an oil formulation of fenitrothion at a rate of 210 g active ingredient/ha by DC-6 aircraft, spray deposit samples were obtained from ten locations on a sampling transect which was perpendicular to flight lines. Sampling stations spanned four swath widths. Deposit samples consisted of new growth of dominant conifer species obtained from four sides of the crown (upwind, downwind, and each side).

Results and Discussion:

The measured deposits in foliage were highly variable between individual sample sites within spray blocks and between spray blocks. The data indicate that deposits of greater than five times the mean deposit could be expected over up to 5% of the spray area. In addition, one block in six had mean deposits which were significantly higher (by a factor of two) than the mean deposit for all six blocks. The magnitude of measured deposits were very similar to those measured in other jurisdictions where spray is delivered by large aircraft, but approximately twice the magnitude of deposits associated with small aircraft spraying.

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4. USE, ENVIRONMENTAL OCCURRENCE, AND EFFECTS OF TRI-n-BUTYLTIN CONTAINING COMPOUNDS IN THE ATLANTIC REGION - (W. Ernst, G. Julien, K. Kieley, P. Hennigar, K. Doe, and M. Thompson).

Introduction:

Organotin compounds are becoming popular components of marine antifoulants because they are more effective than traditionally used copper-containing compounds. The full use pattern of organotin-containing compounds is unknown; however, such antifoulants/preservatives are used in marine paints by the military, merchant shipping, and private pleasure craft owners. They are also used to prevent fouling in aquaculture systems and as preservatives for lobster traps. Concern over the environmental implications of such uses is increasing because of the toxic effects of organotins on marine fauna, particularly bivalve molluscs, at extremely low concentrations. Shellfish rearing and harvesting is an important industry in the Atlantic Region.

There has been limited sampling for environmental residues of organotins in the Atlantic Region and the data base must be improved to evaluate marine organism exposure. The bioavailability of organotins which are in marine sediments must also be determined to assess the hazard that resides in such matrices present.

Objectives:

The objectives of these studies were to: 1. determine the regional use patterns of tri-n-butyltin (TBT) containing products, particularly those that have the potential to contaminate marine environments; 2. select the most appropriate sites and matrices to determine environmental occurrence of TBT residues based on the use pattern data; and 3. conduct a series of bioassays to determine the toxicity of TBT-contaminated marine sediments.

Methodology:

a) Use Pattern Assessment - Information was solicited from: existing Agriculture Canada, Environment Canada and Statistics Canada data as well as regional formulators, distributors, and end users. Data collected included: identity of products in use; market sector; geographic distribution; and quantities sold or used.

b) Environmental Survey - A number of sites were selected for sampling including areas of: shipbuilding and high ship traffic (two sites); pleasurecraft only (two); intensive fish farming activity (two); important shellfish growing (one); and a control (one). At each site, samples of sediment, water, and blue mussels (*Mytilus edulis*) were obtained. Samples were obtained from two to four locations at each site and analyzed for monobutyltin, dibutyltin and tributyltin content.

c) Laboratory Bioassays - Three species of marine organisms (polychaete worm (*Nereis virens*), Baltic clam (*Macoma balthica*) and blue mussel (*Mytilus edulis*)) were exposed to bis (tri-n-butyltin) oxide (TBTO) for 15 days under various conditions. These included: introduction of animals in test chambers which had marine sediments intentionally contaminated with TBTO; placement of animals in test chambers and subsequent introduction of TBTO contaminated sediments which resulted in more particulate suspension in the water column; and exposure of animals to TBTO dissolved in water.

Results and Discussion:

a) Use Pattern Assessment - A total of 3 440 kg of TBT were used in the Region during 1986/87. The main use categories were: antifoulants (54%); lobster trap preservatives (24%); and preservatives, germistats, and slimicides (23%). The sector with the greatest amount of TBT antifoulant use was commercial marine (57%), followed by pleasure craft and miscellaneous (35%), and military (8%).

b) Environmental Survey - Most water samples did not contain detectable concentrations of mono-, di-, or tributylin (level of detection 0.025 µg/L). However, isolated sample stations had concentrations as high as 0.56 µg/L. Sediment and tissue concentrations of butylin were comparable at individual sampling locations. The highest concentration of butyltins (mean 1.9 µg/g) were found in shipbuilding/high ship traffic areas and aquaculture sites. Smaller concentrations (mean 0.05 µg/g) were found in pleasurecraft areas. In all environmental samples, tributyltin was detected in the greatest concentration followed by dibutyltin and monobutyltin.

c) Laboratory Bioassays - The 15-day LC_{50}'s for mussels, marine worms, and clams were very similar; being approximately 18 mg/L based on nominal concentrations, when they were placed on undisturbed contaminated sediments. Contaminated sediments which were introduced to test chambers via "dumping" through the water column, proved to be 1/3 more toxic. Dissolved TBT was approximately 700 times more toxic than when bound to undisturbed sediments. Mussels exposed to contaminated sediments accumulated TBT quite rapidly with tissue concentrations reaching maximum values with 5 days of exposure.

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5. AQUATIC TOXICITY OF CHLOROTHALONIL - (J.H. Young, K.G. Doe and W.R. Ernst)

Introduction:

Chlorothalonil is a potato fungicide which is used extensively and intensively in the Atlantic Region. A potato crop may receive seven to ten applications of the product BRAVO 500 during a single growing season. Aquatic contamination by chlorothalonil during such intensive use, either from aerial drift or off-field movement of contaminated soil particles, is almost a certainty. There is very little published information on the toxicity of chlorothalonil to aquatic organisms. A study was undertaken, therefore, to evaluate the chemical's lethal and sublethal effects on several species of aquatic organisms.

Methodology:

The acute lethal toxicity (96-h LC_{50}) of both technical chlorothalonil and the formulated product BRAVO 500 to rainbow trout (*Salmo gairdneri*) was determined. For the water flea (*Daphnia magna*), stickleback (*Gasterosteus* sp.), blue mussel (*Mytilus edulis*) and soft-shell clam (*Mya arenaria*), acute toxicity tests were conducted using only the formulated product. Survivors of the *Daphnia magna* acute toxicity tests were observed for 21 days in clean water to determine if sublethal effects on growth and reproduction occurred. An uptake and depuration experiment was conducted on mussels at sublethal exposure levels of BRAVO 500.

Results and Discussion:

There was a slight difference in the toxicity of BRAVO 500 and technical chlorothalonil to rainbow trout with 96-h LC_{50}'s being 69 and 76 µg active ingredient/L, respectively; however, this difference was not significant. The 96-h LC_{50} value for marine stickleback was approximately 73 µg active ingredient/L. *Daphnia magna* was the most sensitive invertebrate species tested and the 48-h EC_{50} (immobilization) ranged from 97 to 172 µg active ingredient/L. Blue mussels and soft-shell clams were more resistant with the 96-h LC_{50}'s being 6 and 35 µg active ingredient/L, respectively. The maximum bioconcentration factors for blue mussels exposed to mean chlorothalonil concentrations of 168 µg/L ranged from 0.6 to 10.6. When mussels were placed in clean, flowing seawater, chlorothalonil was depurated to below 0.01 µg/g within ten days. These results demonstrated the toxic potential of chlorothalonil to aquatic organisms and are an indication of the necessity of protecting watercourses from direct or indirect introduction of this chemical.

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6. REVIEW OF THE KNOWN EFFECTS OF FENITROTHION ON POLLINATORS, BIRDS AND AQUATIC FAUNA -

(R. Plowright, P. Kevan, L. White, D. Busby, P. Pearce, W. Fairchild, W. Ernst, and T. Pollock)

Introduction:

Fenitrothion has been used in the Atlantic Region since its first experimental application in 1966. It has been monitored and researched and has been the subject of several reviews, the last comprehensive one by the National Research Council of Canada (1977). The data gathered has lead to the perception that fenitrothion in forest spray-use patterns causes effects that should be questioned in light of public concern over environmental effects.

Recommendations of the New Brunswick Committee for Environmental Monitoring of Forest insect Control Operations and advisory correspondence from the Atlantic Region Pesticides Advisory Committee reflect ongoing reservations about use patterns of fenitrothion in forestry. These professional concerns and the public unease about environmental "safety" prompted Environment Canada to initiate a review of the environmental effects of fenitrothion spraying.

The Pesticides Issues Team focused on pollinator, songbird, and aquatic effects. The purpose is to identify the magnitude of spray effects; to judge whether these re-examined effects are ecologically disruptive; to identify knowledge gaps; and to determine whether natural resources, which Conservation and Protection has a mandate to protect, are at risk. Based on those findings, C&P formulated a regional stance on the acceptability of current-use patterns of fenitrothion and developed technical and regulatory recommendations pertaining thereto.

Methodology:

Separate technical reviews were undertaken of the effects on pollinators, songbirds, and aquatic fauna. The reviews were essentially distillations of available literature, with the exception that the songbird review also incorporated previously unpublished data and a re-analysis of earlier published information. Sources accessed included papers published in the primary literature, as well as published and unpublished government reports. The literature examined was extensive but not exhaustive – selection of only the most relevant material being made.

Results and Discussion:

Due to the considerable and sustained interest in Canadian forest insect spray programs, the accumulated data base on fenitrothion environmental effects is very large and varies widely in quality, factors which contribute to difficult reviews. Some problems were also encountered in establishing criteria by which negative effects are judged.

No consistent relationship was noted between operational dosage rate and observed biological impact. A possible explanation for the variability is a difference in susceptibility at the population level. While it is generally acknowledged that spray accountability is not particularly well-refined, it was the conviction of the Team that the variability of localized insecticide deposits accounts for most of the measured variability in biological impact.

The pollinator effects review concluded that there is a clear cause and effect relationship between fenitrothion use and population decreases of honeybees, wild bees, and other pollinators. Furthermore, those decreases have caused a disruption of critical ecological processes as demonstrated by the impairment of plant reproductive success.

The bird effects review determined that sporadic mortality of the most vulnerable songbird species has been associated with the fenitrothion forest-spray program, since its inception. There are inherent difficulties in finding avian casualties in the forest; a 50% reduction in brain cholinesterase activity in sampled birds is a better indicator of mortality in the population. Such sampling in operational spray blocks indicates that bird mortality has probably been higher than previously thought. Standard laboratory procedures recognize the inability to adequately predict spray effects on birds in the wild, where they are subject to many natural environmental stresses. Furthermore, available field assessment techniques all tend to underestimate the effects on birds caused by forest spraying. Recognizing the inadequacies of available measurement techniques, it must be acknowledged that population reductions in birds have not been shown as a result of fenitrothion use.

Aquatic invertebrate responses are highly variable and not consistently or directly related to spray application rate. Dramatic benthic invertebrate kills have been infrequently observed in lotic systems. Some reductions in benthos can be expected in 15% of streams during operational spraying. In large lentic systems, effects on invertebrates generally do not occur. In streams, benthic invertebrate depletions are generally short-lived. Most population recoveries occur within season and are considered to be tolerable. In some sensitive situations, such as bog ponds, up to 50% reductions in benthic invertebrates occur after treatment with fenitrothion, at simulated operational dosage rates, requiring greater than one year to recover. The ecological implications of such effects have not been investigated, but the potential exists for significant effects on vertebrate fauna, which depend on energy flow through these trophic levels.

While direct fish mortality is not a consideration during operational spray programs, there is evidence of sublethal effects and developmental impairment; the question of population reductions, however, has not been resolved.

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7. THE EFFECTS OF FENITROTHION SPRAYING ON FOREST SONGBIRDS AS DETERMINED BY MEASUREMENT OF CHOLINESTERASE DEPRESSION - (D.G. Busby*, D. Lemon**, and P.A. Pearce*)

Introduction:

Fenitrothion has been the chief chemical insecticide used since the late 1960s to protect Canadian conifer forests against defoliating insects. Aerial spraying programs against the spruce budworm have long been annual events in New Brunswick and other eastern provinces, sometimes several million hectares being sprayed in any given year. The hemlock looper has been a particular problem in Newfoundland.

Management of forest insect pests is a biologically complex problem and the practice of control through chemical insecticide spraying has continued to be a publicly controversial and politically sensitive issue. An accelerating trend to greater reliance on more environmentally benign biological insecticides has been noted.

Advancing spray technology has sought to increase the efficacy of chemical insecticides while reducing the amount injected into the environment. The Canadian Wildlife Service has kept pace by undertaking monitoring and research on the effects of fenitrothion, in different spray packages, on forest songbirds. Sensitive field and laboratory techniques have been developed to assess the effects on birds, one being the measurement of the enzyme cholinesterase, an important indicator of exposure. At currently prescribed operational spray rates, fenitrothion causes toxic effects in birds, which may include mortality, particularly where spray deposits in the target area are high.

Methodology:

The study, with both field and laboratory components, was done in the context of operational spraying against the hemlock looper in Newfoundland and efficacy trials against the spruce budworm in New Brunswick. In Newfoundland, sprays were delivered by a four-engine DC-6 aircraft equipped with boom and nozzle spray hardware and electronic guidance instrumentation. Spraying was done in New Brunswick by a single-engine TBM aircraft fitted with rotary atomizers, guidance being visual. Spray dosage rates were conventional - two applications at 210 g/ha - except that in the New Brunswick experiment a dosage rate of 140 g/ha was included.

The effects on birds were determined by measurement of brain cholinesterase depression in Tennessee, Magnolia, Bay-breasted and Blackpoll Warblers, and in White-throated Sparrows sampled in the sprayed forest and unsprayed control areas. Cholinesterase depression of 50% in birds in the wild, where they are subject to many natural environmental stresses, is considered to be a life-threatening threshold.

Results and Discussion:

In Newfoundland, 17% of all birds sampled exhibited brain cholinesterase depression of over 50%. However, effects were much more pronounced in two of the six operational spray blocks monitored there. In one of them, 34% of sampled birds suffered cholinesterase depression over 50% after a single spray. In the other, in which there was a split application of sprays, cholinesterase depression over 50% occurred in 35% and 19% of the birds sampled after the first and second spray, respectively. By contrast, in the remaining four blocks the spray impact was light, only 3% to 6% of sampled birds having cholinesterase depression greater than 50%.

In the New Brunswick trials, 17% to 18% of the sampled birds suffered cholinesterase depression greater than 50% in both the heavy (210 g/ha) and light dosage (140 g/ha) block, respectively. Both spray regimes caused an impact on birds greater than seen previously in an operational spray context in New Brunswick since 1978, when cholinesterase analysis became our standard for assessing spray effects on birds. In the present study, responses to the spray were greatest in the White-throated Sparrow, levels of cholinesterase depression being comparable to those determined in an earlier investigation in which severe reproductive and behavioural effects were demonstrated.

This investigation illustrated the great variability in the response of birds within a spray regime, insecticide formulation, delivery and emission factors all being held constant, supporting the findings of other studies on the effects on birds from the spraying of fenitrothion and other forestry insecticides. Variability may be a function of forest structure, terrain, local meteorological conditions, and of the overswathing that occurs during operational spraying, or any combination of factors that results in spray deposits, and thus exposure of birds, being relatively high. Although no further light was shed on the matter, earlier studies by the Canadian Wildlife Service suggested that aspects of forest spray technology are relevant to the risk to birds. It would be difficult to factor out the critical elements in a field situation where there are so many obscuring variables.

Reduction of the amount of insecticide active ingredient in the chemical spray formulation is desirable from an environmental standpoint, but the results of our study indicated that such a direction may not necessarily be accompanied by a lowered risk to birds.

This investigation reinforces our position that the margin of safety of fenitrothion for forest songbirds is narrow, and contributed to a decision to undertake a review of the effects of that insecticide on birds, with the object of determining whether a re-evaluation of the forestry use-pattern should be sought.

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8. NEW BRUNSWICK SUBSURFACE DRAINAGE PROJECT: A STUDY OF EFFECTS OF INTENSIVE AGRICULTURAL PRODUCTION ON WATER QUALITY - (H.J. O'Neill, T.L. Pollock, H.S. Bailey, P. Milburn, J.E. Richard, and C. Gartley)

Introduction:

Elevated nutrient levels in surface waters draining agricultural areas and chemical contamination due to pesticide usage has been documented in several areas of North America. Pesticides may reach ground and surface waters via surface runoff, erosion, leaching, spray drift, improper container disposal and accidental spills. Large amounts of pesticides are used annually in the potato growing industry of the Atlantic Region. In co-operation with Agriculture Canada, and the New Brunswick Department of Agriculture, the Water Quality Branch (WQB), Atlantic Region, undertook a study into the presence of in-use pesticides in subsurface drainage from five potato fields in northeastern New Brunswick. The federal and provincial departments of agriculture were interested principally in the export of nutrients from the study sites.

Methodology:

Due to climatic conditions, few pesticides were used in 1987. However, dinoseb (Dytop 300) was used as either a pre-emergent herbicide or as a dessicant at some sites. Tile outflow was collected in the spring and during pre-application and post-application rain events by lay collectors and quantitated for major ions and dinoseb. Dinoseb analysis was carried out using an in situ acetylation as developed by the National Water Research Institute (NWRI).

Results and Discussion:

The in-use pesticide dinoseb was observed in tile effluent from three potato fields in the spring of 1987 representing carry-over from 1986 applications. Levels ranged from 1.1 to 0.11 µg/L. One site indicated a persistence of 11 months in the soil matrix. Dinoseb was also reported in post-application tile effluent with a single highest observation of 44.0 µg/L. Subsequent sampling until season end indicated diminishing dinoseb levels. Major ion data indicated shifts in calcium, alkalinity, potassium, nitrate and total nitrogen concentrations as a result of fertilizer application. Preliminary data from the spring of 1988 confirmed carry-over from the previous growing season and indicated trace level carry-over of 23 months at one study site.

Mass balance calculations indicate that the in-season sampling carried out by the WQB accounted for 0.001% of the dinoseb applied to two study fields.

This project will be completed at the end of the 1988 fiscal year. An interim report is available and a final report will be prepared at project completion.

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9. FEDERAL-PROVINCIAL DRINKING WATER SOURCES TOXIC CHEMICAL SURVEY - (Water Quality Branch, Atlantic Region)

Introduction:

The fiscal year 1988 to 1989 is the last of a four-year joint federal-provincial undertaking involving the Atlantic Region's Water Quality Branch (WQB), Health and Welfare Canada, the New Brunswick and Nova Scotia provincial departments of Health and the Prince Edward Island and Newfoundland departments of Environment. Ten percent of the population of Newfoundland, seventy percent of New Brunswick, fifty percent of Nova Scotia, and nearly all of Prince Edward Island depend upon groundwater for domestic purposes. This study involves the collection and analysis of raw surface and ground sources serving various municipalities in each Atlantic Province. Health and Welfare Canada is investigating various volatile organic materials in raw and treated water while the Water Quality Branch is interested in major ions, metals, nutrients, environmental contaminants, and pesticides in raw water only.

Methodology:

Ten municipal raw water sources were sampled in each Atlantic Province in duplicate during the spring and fall. Collection was carried out by WQB personnel in New Brunswick, Nova Scotia and Prince Edward Island and by provincial personnel in Newfoundland. Volatile organic samples were shipped to the Health and Welfare contract laboratory and all other samples were quantitated by the Analytical Services Division of the WQB. Volume of sample and preservation techniques were matched on a parameter-specific basis. Parameter selection is determined jointly and includes: major ions, metals, nutrients, chlorinated phenols, chlorinated benzenes, organochlorine insecticides, polychlorinated biphenyls, carbamate insecticides, organophosphorus insecticides, and polyaromatic hydrocarbons.

Results and Discussion:

A data summary report has been prepared for each province for 1985 and 1986, with the 1987 summary currently in preparation. The ubiquitous organochlorine alpha-BHC and the polyaromatic hydrocarbon fluoranthene have been observed in several sources. Isolated observations for some in-use organophosphorus compounds have been reported at levels just above detection. Any pesticide observations for which Health and Welfare has set guidelines, have been below the guidelines. Health and Welfare Canada has reported some volatile organic material in raw and treated sources. Perchloroethylene has been noted in two instances indicating an emerging area of concern. These locations were followed up by the provincial departments responsible. The aesthetic guideline for colour, has been exceeded by several municipalities that depend on surface water sources. Manganese and iron concentrations have also been reported in excess of the aesthetic guideline.

The 1988 fiscal year will be the last year for this program in its current format.

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10. AN APPLICATION OF SPANS TECHNOLOGY TO TOXIC CONTAMINANT MONITORING IN THE ATLANTIC REGION - (H.J. O'Neill and W.B. Hanna)

Introduction:

Concern has increased over the presence of toxic organic chemicals including pesticides in the freshwater, bottom sediments, and biota of the Atlantic Region. Most environmental contamination is either a direct result of, or enhanced by anthropogenic activity. It was felt that land use data could be used to identify areas of potential pesticide and contaminant input on a regional basis. Land activity information, however, has not been easily accessible to water resource managers and investigators. The objectives of this study were to identify and rank areas of potential anthropogenic sources of contaminants based on land use data; to verify the resultant potential sources by use of existing Water Quality Branch data; and to illustrate how such information could be used as an information base during the design of monitoring networks and site priority.

Methodology:

All relevant data sets were obtained from the Canada Land Data System of Environment Canada and prepared for use. The micro-computer based SPANS geographic information system was used to conjugate land use information. It is generally accepted that the presence of certain factors in an area will increase the potential for higher levels of pesticides or contaminants. By identifying the areas in which these factors are prevalent, one may infer the existence of possibly higher toxic chemical loads. SPANS was used to conjugate land use information in order to produce a hypothesis map entitled "Potential Sources of Toxics". This map was tested using in-house Water Quality Branch (WQB) data.

Results and Discussion:

Two maps were generated through the conjugation of land use, land capability, industrial location, and demographic data bases. The Potential Sources of Pesticides map illustrates the potential sources of agricultural pesticides, while the "Potential Sources of Toxics" map illustrates known agricultural, industrial, and population factors. The use of a relative scale ranging from "Very High" potential to "Low" potential was employed to rank contaminant potential on a regional scale. An areal analysis of this map indicated that approximately 10% of the region fell into the "High" to "Very High" categories.

An examination of empirical data confirmed the general accuracy of this map. Of the 55 observations of toxic contaminants (PAH including fluoranthene, DDT, and PCBs) ranked "High" and "Very High", 78% (43) were located in areas ranked "High" and "Very High" on the hypothesis map. Additionally, a strong correlation between potential pesticide input and observed nutrient levels supported the validity of the hypothesis map.

Monitoring networks for individual toxic contaminants may be enhanced by following the approach of this study. The occurrence of a toxic chemical in the environment is a function of many factors, but by converting information relevant to a specific toxin (contributing industries, soil types, etc.) into maps and conjugating them via matrix overlays, accurate predictive maps may be created. Making use of these maps (by identifying "hot-spots", etc.) will assist in selecting monitoring locations by eliminating some of the guesswork currently involved.

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11. PERSISTENCE AND FATE OF DELTAMETHRIN SPRAYED ON A POND AND STREAM IN PRINCE EDWARD ISLAND - (R.J. Maguire, J.H. Carey, and H.-B. Lee)

Introduction:

Deltamethrin, one of the photostable synthetic pyrethroid insecticides, is the most potent insecticide known. Since deltamethrin is also very toxic to aquatic invertebrates and, directly or indirectly, to organisms which feed upon these invertebrates, its use is normally restricted to areas removed from streams and ponds. As part of a joint National Water Research Institute - Environmental Protection (NWRI-EP) Atlantic Region - Water Quality Branch (WQB) Atlantic Region study on the effects of deltamethrin on stream biota, we examined the persistence and fate of deltamethrin in a pond and stream after a direct overspray.

Methodology:

After the spraying of deltamethrin on a pond and stream adjacent to a potato field in Prince Edward Island in July 1986, samples of subsurface water, surface microlayer, suspended solids, and sediments were collected. These samples were analyzed for deltamethrin and its stereoisomers, and four of its most prominent degradation products. These products were: cis-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid (DBCA); 3-phenoxybenzyl alcohol (PBalc); 3-phenoxy-benzaldehyde (PBald); and 3-phenoxybenzoic acid (PBacid).

Results and Discussion:

Deltamethrin sprayed on the pond and stream disappeared quickly from water, with a half-life of about one hour. Major routes of degradation or dissipation were:

1). chemical and photochemical conversion to inactive (2+2')-deltamethrin stereoisomers; and

2). hydrolysis with subsequent oxidation of products.

No residues of deltamethrin stereoisomers or any of the four major products sought were found in water or sediment 11 days after spraying. Laboratory experiments on the volatilization of deltamethrin formulations from sprayed water as opposed to subsurface-injected water, indicated that volatilization from the surface microlayer was a very fast process which could be the major route of dissipation of deltamethrin, or any lipophilic pesticide, sprayed on the surface of water. We have previously made this observation with fenitrothion sprayed on a pond during forest spraying against the spruce budworm in New Brunswick.

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12. **PESTICIDE MIGRATION AND FATE IN GROUNDWATER** - (R.E. Jackson, Study Leader, M.W. Priddle, S. Lesage, P. Lapcevic, J.P. Mutch, and K.S. Novakowski)

Introduction:

The objective of this study is to assess the migration and fate of the insecticide aldicarb, the active ingredient of Temik, in groundwaters beneath potato fields on Prince Edward Island. During the past three years the groundwater quality has been monitored beneath three fields to which aldicarb has been applied. The monitoring has been conducted by collecting groundwater samples from each of the 50 monitoring wells installed at the field sites. Chemical analysis of the samples was conducted at the National Water Research Institute and at the Water Quality Branch Labs in Moncton, N.B.

Results and Discussion:

Persistence of the toxic aldicarb species - aldicarb sulfoxide and sulfone - has been observed in P.E.I. groundwaters of low pH and high nitrate. It seems that high aldicarb values rarely ever appear without elevated nitrate concentrations. Clearly, the high permeability of the P.E.I. soils offers a physical explanation for this phenomenon; however, the low pH values suggest that there may be a chemical reason as well. We have shown by geochemical simulation that the oxidation of ammonium nitrate fertilizers produces nitrate and a low pH groundwater. Under the low pH and low temperature environment in the P.E.I. soils, aldicarb degradation to less toxic species is reduced. Consequently, the degradation of fertilizer residues on P.E.I. appears to inhibit the degradation of the pesticide residues. This phenomenon could be avoided by application of the Temik following plant emergence in late June rather than at seeding in May; this would allow the soil temperature to rise considerably and for the bulk of the ammonium oxidation to take place in the absence of aldicarb.

A further reason for applying Temik at plant emergence rather than at seeding is that Temik is a systemic insecticide that relies on uptake by the plant's roots to protect the plant from predation by aphids and potato beetles. Since no roots exist at the time of seeding, uptake is minimal and leaching is promoted.

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PESTICIDES PROGRAM IN THE QUEBEC REGION

Atrazine, Metolachlor, MCPB, Captan, Mancozeb, Phorate Carbaryl, Azinphos-methyl, Endosulfan, Aldicarb, Chlordane, Paraquat, Picloram, BT, Chlorpyrifos, Fonofos, Methoxychlor, Parathion, Permethrin, Terbufos, Carbofuran, Diazinon, Methamidophos, Dinoseb, Thiram

1. **HANDBOOK OF THE PRIMARY PESTICIDES IN USE IN QUEBEC** - (D. Cossette, I. Giroux, R. Poulin et al., contractors, SAGE Ltée, Quebec)

Introduction and Objectives:

The purpose of this study is to prepare a handbook of the primary pesticides used in Quebec in agricultural, forestry and urban environments. It will provide Environment Canada with the information it requires to plan joi' initiatives aimed at assessing the environmental impact of pesticides in Quebec.

Methodology:

The pesticides that cause the most serious concern in Quebec have been selected on the basis of the following criteria: quantity sold, toxicity, persistence, carcinogenicity, and rate of application.

The handbook comprises three volumes: Volume 1 (confidential) constitutes an overview of the situation. It describes the processes used to select pesticides of greatest concern in Quebec and the forty pesticides selected. Chapter 2 describes the process for selecting the nineteen drainage basins of greatest concern from among the 122 in Quebec. Chapter 3 defines the concept of guild and indicates the main species (birds and fish) likely to be exposed to pesticides. Chapter 4 presents and discusses the results obtained. Volume 2 covers active ingredients and Volume 3 (confidential) covers drainage basins.

Results and Discussion:

In general, herbicides are the most commonly used pesticides in Quebec. We retained atrazine, metolachlor and MCPB. With respect to fungicides, captan and mancozeb are important. With respect to insecticides, the situation varies from one region to another, with phorate and carbaryl being among the most commonly used. In addition to these products of primary interest for all of Quebec, azinphos-methyl, endosulfan, aldicarb and chlordane are potentially toxic or present a high risk of exposure for organisms in the natural environment.

The primary species recognized as being sensitive to direct herbicide exposure are fish and a number of non-target plant species. In the case of insecticides, man, aquatic invertebrates, fish, terrestrial fauna, birds and bees are particularly vulnerable. In the case of fungicides, fish are the most sensitive species.

Thirteen of the 40 pesticides selected are highly persistent in one or more of the compartments studied, namely soil, water and aquatic organisms. They are: dinoseb, MCPA, paraquat, picloram, BT, chlordane, chlorpyrifos, fonofos, methoxychlor, parathion, permethrin, phorate and terbufos.

In corn and grains, birds which feed in the soil early in the season and on plants during the season are more likely to be affected by pesticides than other birds. Paraquat and carbofuran used in pasturage are toxic for birds and could affect several species of omnivorous, granivorous, and insectivorous birds.

In crops of small fruits and fruit trees, the insecticides azinphosmethyl, carbofuran, diazinon and endosulfan cause the most concern. Approximately thirty species of birds frequent these crops as these products are being applied.

In market garden produce, granular products may pose a risk for birds feeding in the soil, as well as certain toxic products for birds, such as azinphos-methyl, carbaryl, carbofuran, chlorpyrifos, diazinon, endosulfan, methamidophos, parathion, dinoseb, paraquat and thiram.

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2. SOCIO-ECONOMIC PROFILE OF AND PESTICIDE USE BY FARMERS EMPLOYING CONVENTIONAL, INTEGRATED PEST MANAGEMENT OR BIOLOGICAL CONTROL TECHNIQUES: FRUIT AND VEGETABLE GROWERS IN QUEBEC - (Hélène Boudier)*

Introduction and Objectives:

Increased, or generalized, use of integrated management practices (IPM) should reduce environmental problems caused by pesticides and their handling. Such changes can only be effectively encouraged if the socio-economic background and behavioural profile of producers who already employ the methods in question are known.

The first objective of this research was, therefore, to compare the socio-economic background of IPM users growing crops which involve the use of a large quantity of pesticides (vegetables, small fruit, apples and potatoes) with a control group of conventional farmers who produce the same crops and a group of farmers who employ biological control. The second objective was to compare group attitudes towards the use of pesticides.

Methodology:

The methods used were nondirective interviews and questionnaire-type surveys conducted at the homes of 384 farmers. They were selected from among vegetable, small fruit, apple and potato producers south and north of Montreal, and in Mauricie-Nicolet, where scouting systems existed. Three categories of respondents were defined: 203 conventional farmers, 127 IPM users, and 22 farmers who employ biological control techniques.

The questionnaire comprised eight sections: socio-economic profile of the respondents and their agricultural activity; farming practices; product marketing; attitude toward pesticides; views on pesticides; observation of the environment; sources of information; and motivation.

Results and Discussion:

IPM users were better educated than farmers employing conventional practices, but less educated than farmers employing biological control techniques. They more often formed corporations (35%) and were more involved in professional organizations than in their community. The opposite was true for conventional farmers. On average, IPM users had larger farms (101.4 ha) than conventional farmers (67.9 ha) or farmers employing biological control techniques (32.8 ha). The average gross income of this group was almost three times higher than that of conventional farmers and ten times higher than farmers using biological control techniques. Product appearance was the most important criteria of quality for conventional farmers and IPM users, whereas nutrition was the most important criterion for farmers who used biological control.

More IPM users considered themselves businessmen, and, more IPM users and farmers who used biological control techniques kept crop management records. Significantly more IPM users had invested in drainage and irrigation. With respect to farming practices, the survey revealed that many methods other than chemicals were used to control certain pests or problems. The most commonly used techniques were harrowing, tilling, machine weeding and crop rotation. IPM users and conventional farmers used the same techniques in similar proportions.

The selection of pesticides by IPM users was based primarily on personal experience. They also relied on manuals published by the Quebec Department of Agriculture, Fisheries and Food, phytosanitary warnings and antiparasitic treatment handbooks for pesticide information. The crop was the primary factor in determining the differences, and not membership to a particular group, except of course for farmers employing biological control techniques.

In cases in which IPM users used pesticides, we saw no difference in the disposal of the product remaining after use, the product used, or the training received in this field between IPM users and conventional farmers. However, more IPM users keep pesticide inventory records (46% compared with 27%).

Fifty-six percent of IPM users and 41% of conventional farmers observed diseases following the application of these products. The health of wildlife species is also affected: 9% of the growers observed dead animals after the application of pesticides. Birds were the main species affected, but cats, dogs and fish were also mentioned.

Fifty-seven percent of IPM users were willing to pay more for a product that was less toxic to the user, compared to 40% of conventional farmers. Similarly, 46% of IPM users and 38% of conventional farmers were willing to pay more for a less persistent pesticide and 38% and 31% for a more specific pesticide.

On the basis of socio-economic background and views on pesticides and the environment, it is clear that there are appreciable differences among the three categories of producers. While farmers who employed biological pest control techniques did so primarily for environmental reasons, IPM users chose IPM primarily for economic reasons, even though their views on pesticides were similar to those of farmers using biological control techniques.

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3. PRESENCE OF AGRICULTURAL PESTICIDES IN AQUATIC SYSTEMS IN QUEBEC - (C. Langlois and H. Sloterdijk)

Introduction:

In Quebec, 2.7 x 10^6 kg of pesticides are used every year in agriculture against all types of pests that are harmful to crops: weeds, insects, disease, fungus, rodents, etc. The effect of pesticides on these organisms depends on chemical groups. Periods of use vary depending on the pesticide (purpose and target organism), the period during which the problem appears, and weather conditions. Most pesticides are used in the spring (May-June).

The inventory of pesticides found in the aquatic environment in Quebec is still very rudimentary. The Inland Waters Directorate in the Quebec Region carried out a monitoring program limited to chlorinated organic pesticides (organochlorines) in the St. Lawrence River. Commonly used pesticides (carbamates, triazines, amide derivatives, phenoxy acids and organophosphorus pesticides) were not included. In light of the large amounts involved and the toxicity of certain pesticides to non-target organisms, their persistence in the environment or their accumulation in living organisms, it was crucial to establish a clear picture of the situation.

The objectives of this study were to provide data to re-assess pesticides use, provide information on occurrence and movement and develop an evaluation and monitoring program for pesticides commonly used in Quebec.

Methodology:

The southwest region of Lake Saint-Pierre was studied. Here, the highly agricultural Yamaska and Saint-François river basins constitute important sources of pesticides. Various components of the aquatic environment were studied: bottom sediments, suspended sediments, water and juvenile fish (spottail shiner, yellow perch, emerald shiner). Stations were located 7.5 km and 2 km from the mouths of the Yamaska and Saint-François rivers, respectively. Sampling began in late June and ended in October. For each river, a total of nine water samples were taken at a frequency of one a week (July-August and once in the fall). Samples were taken on four occasions in July and early August for suspended sediments (collected by centrifugation) and water (passed through a resin column). Samples of bottom sediments were taken at three stations in each river. Juvenile fish were collected at two stations in each river on three occasions in July, August, and September. The following pesticides were analyzed in each medium (water, suspended and bottom sediments, fish):

Carbamates:	butylate, aldicarb, carbofuran
Triazines:	atrazine, metribuzin, simazine
Phenoxy acids:	2,4-D, 2,4-DB, 2,4-DP
Organophosphorus:	diazinon
Amide derivatives:	alachlor, metolachlor
PCBs/OCs:	Total arochlor (PCBs), hexachlorobenzene, aldrin, heptachlor, mirex, alpha-, beta- and gamma-BHC, cis- and trans-chlordane, p,p'-DDE, o,p'-DDD, o,p'-DDT, p,p'-TDE, p,p'-DDT, methoxychlor, heptachlor epoxide, alpha- and beta-endosulfan, dieldrin, endrin.

Results and Discussion:

Only five of the 39 pesticides analyzed for in water samples from the Yamaska exceeded the detection limits: 2,4-D (10% of the cases), 2,4-DP (40%), picloram (10%), metolachlor (50%), and atrazine (100%). In the Saint-François, only 2,4-DP (50%) and atrazine (100%) were detected. If the results are added using a resin column, six of the 23 organochlorinated pesticides analyzed exceeded the detection limit in the Yamaska : α-BHC (75%), lindane (100%), cis-chlordane (100%), trans-chlordane (50%), o,p'-DDT (25%) and p,p'-DDD (50%). In the Saint-François, five were detected: α-BHC (100% of the cases), lindane (100%), cis-chlordane (25%), trans-chlordane (25%) and o,p'-DDT (25%).

PCBs were detected in all bottom sediment samples, but only one of the 40 pesticides analyzed for was detected in the Yamaska, atrazine (30% of the cases). Pesticides were not detected in the bottom sediments of the Saint-François. The results for suspended sediments were: Yamaska: PCBs (100%), atrazine (25%); and Saint-François: PCBs (100%).

Besides the PCBs present in all of the juvenile fish sampled, only two of the 40 pesticides analyzed for were above the detection limit: lindane (16% in *Notropis hudsonius* only) and p,p'-DDE (100%).

The concentration of atrazine in water was 2 to 10 times greater in the Yamaska than in the Saint-François which is explained by the higher rate of application in the Yamaska drainage basin (2.11 kg/ha) than the Saint-François (1.90 kg/ha). In Quebec, atrazine has a high rate of application. Chlordane, a highly persistent and moderately toxic pesticide, was still detected in the water even though its use was discontinued in December 1985.

The variation in quantity and concentration of pesticides detected in water samples is similar to the variations observed in nutrients (NO_2-NO_3, total phosphorus). Pesticide concentrations peak in early summer owing to the massive use of fertilizers (N, P, K) and pesticides, then concentrations subsequently decline.

It is difficult to detect all pesticides present in the aquatic environment in a single summer. Variations in application periods, climatic conditions, physiochemical and biological transformations of pesticides in the aquatic and terrestrial environment, and timing between sampling and application of pesticides, affect the quantity and concentration of pesticides found in aquatic systems.

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4. DEVELOPMENT OF A SIMPLE, ADAPTABLE TOOL FOR THE ASSESSMENT OF GROUNDWATER VULNERABILITY TO CONTAMINATION BY PESTICIDES - (J.-P. Villeneuve, O. Banton, P. Lafrance, C. Blanchette and S. Deschênes)*

Introduction and Objectives:

The purpose of this project was to develop a methodology for assessing the vulnerability** of groundwater to pollution at hydrogeological sites, using existing information on each particular site.

The objective of developing this methodology was to provide a tool for assessing the relative vulnerability of sites to groundwater contamination from various sources, taking into consideration the parameters governing vulnerability. This tool will be useful for analyzing the relationships between application practices, land-use, and products, and subsequently their effect on the contamination of groundwater. This tool could be used to guide the selection of future sampling sites and parameters to be characterized at the sites.

This project also includes the creation of a program for mapping the results of the vulnerability assessment.

Methodology:

The development of the methodology to assess groundwater vulnerability was carried out in five main stages: review and assessment of evaluation and representation methods used; development (adaptation) of a methodology applicable specifically to Quebec; application of the methodology at the sites; programming on micro-computer with graphic outputs; and report publication.

Results and Discussion:

The vulnerability of a groundwater system to contamination is a complex, poorly-defined concept which may represent not only sensitivity and vulnerability to contamination but also the natural conditions which affect penetration, propagation, and even purification in the environment. The various factors involved in and influencing groundwater vulnerability to contamination are those related to penetration and propagation in the water table. Various methodologies for assessing groundwater pollution potential including: expert evaluations, index methods, and mathematical modelling of pesticide transport were studied.

A methodology for assessing groundwater vulnerability must take into consideration the conditions of the site, the persistence (degradation constant), and the mobility (or retardation factor determined by the value of the distribution coefficient K_d) of the contaminant in the unsaturated or saturated zones. It is the representativity and level of use of these attenuation factors, related to the importance placed on factors of risk and effects of contamination, that determine the utility or quality of an assessment of groundwater vulnerability. Among the different methodologies for assessing groundwater vulnerability to contamination, the only type of method that could meet the concerns and objectives appeared to be mathematical simulation models of contaminant transport.

The results of deterministic simulation of pesticide transport - the prediction of contamination by this pesticide - are very sensitive to variations in input parameters, such as adsorption and degradation. In light of the spatial and temporal variability of site characterisitics, the representativity of these results is very uncertain. A stochastic approach to simulating the fate of a pesticide in the unsaturated zone is a good alternative since it takes into account the variability of soil characteristics and therefore the variability of parameters related to water flow and contaminant transport. For real site conditions, the stochastic use of a deterministic convective model is numerically equivalent to the stochastic use of a deterministic convective-dispersive model.

To develop the new VULPEST model, it was assumed that transport can be adequately modelled by the differential equation of advection. An exact solution is used to solve this equation in order to reduce the computation time and minimize calculation errors.

A deterministic model shall be used as part of a stochastic simulation approach (Monte-Carlo type) to take into account the spatial variability of the hydrogeological characteristics of the soil at the site. This approach consists of performing a sufficient number of simulations. The parameters for each simulation are established by randomly selecting distributions of the values assigned to each parameter.

Different types of results are obtained from such simulations. The model provides a stochastic breakthrough curve corresponding to the temporal integration of the breakthrough curves of each Monte-Carlo simulation. It also provides the maximum concentration, the average annual concentration, and cumulated mass of pesticide. The results can be processed statistically, in terms of the risk (probability), and exceedance of values, such as norms and reference values entered by the user.

The VULPEST model has been translated in the form of interactive software. The structure of the software facilitates the entry of data. Based on a pull-down menu system, it offers direct visualization of the data entered, the selected parameter distributions, and the simulation results. It also allows the management of the various files.

The model has been applied at two Quebec sites (region of Portneuf and Saint-Augustin), with two different pesticides. The results obtained are very realistic and satisfactory, despite the lack of certain necessary data.

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**Vulnerability, in this context, is defined as any introduction of contaminants into the system.

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5. CANADIAN WATER QUALITY GUIDELINES FOR PESTICIDES - (M. Wong)

Introduction:

The Canadian Council of Resource and Environment Ministers (CCREM) published the first edition of the Canadian Water Quality Guidelines in 1987 to harmonize guidelines recommended for the maintenance and protection of designated water uses. Guidelines have been developed for chemical, physical, and biological parameters. The major water uses addressed are:

a) raw water for drinking water supply;
b) recreational water and aesthetic considerations;
c) agricultural water supplies including irrigation and livestock watering;
d) industrial water supplies; and
e) water to support and protect freshwater aquatic life.

Water quality guidelines are used by Canadian provincial, territorial, and federal agencies in their efforts to assess water quality problems and to manage competing uses of water resources. Recognizing the increasing importance of water quality guidelines in this process, CCREM asked its Task Force on Water Quality Guidelines to prepare water quality guidelines relevant to Canadian conditions.

It must be emphasized that these guidelines do not constitute values for uniform national water quality and that their use will require consideration of local conditions. The guidelines will also be updated as new information becomes available.

One group of parameters requiring guidelines, identified by the CCREM Task Force on Water Quality Guidelines are the in-use pesticides. Although pesticide guidelines are included in the first edition, many of these organochlorine compounds are no longer registered or do not have widespread use in Canada. Concerns are now focused on the newer insecticides, herbicides and fungicides currently being applied in modern agricultural and silvicultural practices.

Methodology:

The CCREM Task Force, following consultation with members, compiled a list of in-use pesticides which urgently required water quality guidelines. Extensive surveys of the world literature regarding the use; the occurrence in water, sediments, and biota; the environmental chemistry and toxicology of the priority pesticides were undertaken. In 1987/88, reviews of the published information for atrazine, carbofuran and glyphosate were performed.

Results and Discussion:

Canadian water quality guidelines for the major water uses were recommended for atrazine, carbofuran and glyphosate. These numerical limits and their accompanying rationale have been submitted to the CCREM Task Force and other scientific experts for their review. These guidelines will be published as updates in the CCREM Canadian Water Quality Guidelines (1987) document following the review process.

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Atrazine, Metolachlor, Chlorpyrifos, Glyphosate, Carbofuran, Lindane, Terbufos, Fonofos, Chlorothalonil, Phorate.

6. PESTICIDES IN THE AQUATIC ENVIRONMENT: ESTIMATING ENVIRONMENTAL RISK USING THE NRCC PERSISTENCE MODEL - (R. Newhook and A. Baril)

Introduction:

Confronted with the assessment of over 450 active ingredients currently registered under the *Pest Control Products Act*, authorities responsible for water quality management in Canada require screening tools to estimate the risk posed to aquatic organisms by pesticides. Estimates of expected environmental concentrations, partitioning, and persistence of pesticides following release into aquatic systems can best be obtained through modelling since this is the only means of synthesizing the numerous processes governing the environmental behaviour of pesticides.

This project was undertaken to estimate the media distribution of the top selling pesticides in two model aquatic systems (lake and pond) using the NRCC PERSISTENCE model. The toxicity to aquatic organisms of these pesticides is discussed in light of their expected environmental concentrations, partitioning characteristics, and persistence.

Methodology:

Data on the physical-chemical properties, partitioning characteristics and transformation rates of the 26 top selling pesticides in Canada (ten insecticides, ten herbicides and six fungicides) were obtained from published reports. The data were evaluated for good laboratory practice, consistency of experimental conditions and protocols, and relevance to environmental situations. Values were thus selected for input into the model. Where measured values were unavailable, extrapolations from known empirical relationships were used. A worst case scenario was modelled by using pesticide input rates calculated from maximum recommended application rates for agricultural uses.

Information on the acute toxicity of these same pesticides to aquatic invertebrates and fish was culled from the published record. Based on these data and the model outputs, pesticides were ranked for toxicity, persistence and expected environmental concentrations and characterized by the dominant compartment of accumulation. The relative risk posed by each pesticide to aquatic animals was subsequently assessed.

Results and Discussion:

Although the model predicted the extent of partitioning between the four compartments (water, suspended solids, sediments, fish) for all 26 pesticides, runs which included degradation and transformation rates were executed for only 14 pesticides because of insufficient input data. In brief, model outputs indicate that the herbicides atrazine and metolachlor are the most persistent compounds regardless of the compartment where they are sequestered. Among those which partition mostly to the water, glyphosate, atrazine and carbofuran are the most persistent, while chlorpyrifos and lindane are the most persistent compounds which sequester predominantly in sediments. Metolachlor partitions equally between water and sediments. It should be pointed out that the model describes the behaviour of the parent compound and not the degradation products which may behave differently.

Acute toxicity values were ranked and average ranks determined for each pesticide and from these it was established that the five most toxic compounds to aquatic invertebrates and fish were (in decreasing order of toxicity): terbufos, fonofos, chlorothalonil, phorate and chlorpyrifos. Among the 14 pesticides for which expected environmental concentrations were predicted by the model, it was found that all nine insecticides were present in the water at levels exceeding, for at least 20 days, the lowest LC_{50} recorded for each compound. In particular, initial concentrations of chlorpyrifos, lindane and terbufos in water also exceeded LC_{50} values averaged for a variety of species tested.

An estimation of risk was also attempted using the Relative Hazard component of the NRCC PERSISTENCE model. This component combines environmental fate information and the lowest LC_{50} value recorded for each pesticide to calculate a Relative Hazard Index under acute and chronic exposure scenarios. Malathion, carbaryl and diazinon were therefore assessed as posing the greatest hazard under both scenarios, most likely because of the extreme sensitivity of certain species to acute exposure to these compounds.

Validation of model outputs was attempted using the published results of selected field studies. The advantages and limitations of using models of environmental fate in screening pesticides for environmental hazard are also discussed.

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**Triazines, Triazoles,
Amide derivatives,
Carbamates, Organophosphates**

7. PESTICIDES IN BILE IN FISH FROM THE YAMASKA RIVER, QUEBEC - (R.J. Maguire and J.L. Metcalfe)

Introduction:

Persistent hydrophobic pesticides accumulate in liver, kidney and other fatty tissues of fish. The bile, however, is capable of accumulating very high concentrations of the more water-soluble pesticides and their conjugates. It may be that fish bile will prove useful as an indicator of contamination by relatively water-soluble pesticides. Although biliary excretion is a removal mechanism, it is possible that chemicals can be re-absorbed from the bile. We are examining the bile and major organs and tissues of 100 fish from different reaches of the Yamaska River in Quebec to determine the organ distribution of a variety of pesticides. The Yamaska River is an excellent site for this work since more than one quarter of all pesticides used for agricultural purposes in Quebec are used in this relatively small basin. Chlorinated pesticides will be determined, in addition to the following classes which are heavily used in the Yamaska basin: triazines and triazoles, amide derivatives, carbamates and organophosphates. The triazine-triazole class, in particular, ranks third of the 45 classes of pesticides in order of priority for re-evaluation under the *Pest Control Products Act*.

Methodology:

Three hundred and fifteen tissue samples were extracted with dichloromethane under both acidic and basic conditions to produce 630 extracts. Lipids were removed from all these samples, and after silica gel column cleanup (producing 2 to 4 fractions for each of the 630 samples) the samples will be analyzed by gas chromatography with electron capture and nitrogen-specific detectors.

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8. BENTHIC MACROINVERTEBRATE COMMUNITY STRUCTURE AS AN INDICATOR OF ECOSYSTEM HEALTH IN A PESTICIDE-CONTAMINATED RIVER - (J.L. Metcalfe and D.R. Barton)

Introduction:

Benthic macroinvertebrate community structure is an accurate bioassessment technique for evaluating the ecological degradation which occurs in rivers as a result of organic and toxic pollution. It's use in Canada has been sporadic, but in Europe a standardized method recently developed in Belgium is extensively used for policy decisions on surface water management. Opponents of assessment techniques involving macroinvertebrates cite the amount of time and degree of skill required for taxonomic identification as a major hindrance to their practical application. However, because environmental conditions are integrated over time, bioassessment techniques become comparable in effort to chemical assessment techniques which, due to their instantaneous nature, are subject to wide fluctuations and require large numbers of measurements to calculate an index representative of water quality. Recent community structure analyses suggest that identification to the more practical "Family" level may be adequate for a valid assessment. Benthic community structure has most frequently been used to assess the impact of organic pollution of a general nature. Stream invertebrate fauna, however, may respond in a predictable and indicative manner to specific pollutants. If so, benthic community structure could be used to characterize rivers and streams according to the kind and degree of pollution present, and to provide an early warning system for the detection of certain toxicants by virtue of their specific effects on benthic organisms. There is little information available on the responses of stream ecosystems to agricultural practices, and this study addresses the knowledge gap. The Yamaska River in Quebec was studied because 26% of all pesticides used for agricultural purposes in the province are used in this relatively small basin.

Objectives:

The objectives of the study were to describe the benthic macroinvertebrate communities associated with and representative of various types and degrees of pollution including pesticides, municipal discharges, and industrial chemicals; to select the best sampling techniques by comparing results obtained with three different methods; and to determine if taxonomic identification to the Family level is adequate for a valid assessment.

Methodology:

Fourteen sites in the Yamaska watershed were selected: five pesticide-contaminated; three controls; and six sites with varying degrees of industrial (mainly textiles) and municipal sewage pollution. Native invertebrates occupying the riffle zones were collected with a Surber sampler, and burrowing organisms with a scoop sampler from pool habitats in early July and late August, 1987. In addition, artificial substrate samplers were set during July and removed after a seven-week colonization period. These samplers standardize the substrate type to reduce variability and collect drifting and resident organisms. Biological samples were preserved on site and submitted to an invertebrate taxonomist for enumeration and identification. Characterization of the sites in terms of occurrence and concentrations of pesticides and other contaminants was conducted under separate investigation.

Results and Discussion:

The three sampling techniques collected different assemblages of benthic invertebrates. Surber samples contained the largest number of species (107), followed by artificial substrates (69), and scoops (58). Scoop samples were dominated by pollution-tolerant aquatic worms (Oligochaeta) at metals and municipal/industrial sites, and by worms and crawling water beetles (Haliplidae) at agricultural sites. Samples from control sites were more diverse and included the more sensitive mayflies (Ephemeroptera) and riffle beetles (Elmidae) in significant proportions. Surber samples were dominated by net-spinning caddisfly larvae (Trichoptera) at all sites except those most heavily contaminated with municipal and industrial effluents, which contained mainly worms. At lesser contaminated municipal/industrial sites, the pollution tolerant *Cheumatopsyche* (a net-spinning caddisfly larva) and *Baetis* (a mayfly) were dominant. Agricultural sites were dominated by isopods, *Baetis*, *Cheumatopsyche* and another net-spinner, *Hydropsyche sparna*. Control site communities had an even distribution of the major invertebrate groups with high percentages of sensitive mayflies (species other than *Baetis* and riffle beetles) as well as a variety of net-spinning caddisflies and some very sensitive stoneflies. Artificial substrate samplers collected high proportions of caddisflies, beetles, and especially mayflies. The metals site was dominated by *Cheumatopsyche* and worms, urban sites by the mayfly *Stenacron interpunctatum* and crawling water beetles, and agricultural sites by flatworms, crawling water beetles or mayflies, especially the genus *Cloeon*. Samples from the most contaminated site contained little else besides pollution-tolerant worms.

Where sites were very polluted, a few pollution-tolerant organisms flourished due to increased enrichment and decreased competition and predation. In these cases, all three sampling methods collected the same organisms and provided similar assessments. Where sites were somewhat less polluted, each sampling method selected for certain types of organisms. The more diverse the community, the more these methods differed in the types of organisms collected. The scoop sampling technique showed the clearest relationships, ranking the sites as controls, metals, agricultural and urban/industrial according to apparently increasing levels of environmental stress.

Level of taxonomic identification did not affect the ability to distinguish the most polluted sites from all others. At intermediate sites, which included agricultural watersheds, Order and in most cases Family level of identification failed to distinguish between degrees of disturbance except to divide four of the agricultural sites into two pairs, one pair more contaminated than the other. An exception was the beetle family (Coleoptera), where crawling water beetles were characteristic of agricultural and municipal (but not heavily industrial) sites. Also, the Family Trichoptera (caddisflies) showed excellent promise as bioindicators, being relatively abundant at all sites. The relative abundance of *Cheumatopsyche* and the number of species of *Hydropsyche*, when considered together, provided a good indication of water quality. Generic identifications were sufficient for most mayflies since agricultural sites usually supported only *Baetis* or *Cloeon*, while control sites tended to have relatively large numbers of *Paraleptophlebia* and *Ephemerella*. Individuals of *Stenonema* were often the most abundant mayflies sampled, and the different species showed varying tolerances to apparent water quality.

The findings represent an important step towards defining the benthic invertebrate communities associated with different types of environmental pollutants, including pesticides applied for agricultural purposes.

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PESTICIDES PROGRAM IN THE ONTARIO REGION

1. DEFINITION OF WATER QUALITY BRANCH - ONTARIO REGION ROLE IN THE CONSERVATION AND PROTECTION PESTICIDES PROGRAM - (J. Struger)

Introduction:

The Water Quality Branch - Ontario Region (WQB-OR) was provided with funding to carry out a portion of the Environment Canada National Pesticides Action Plan, in which certain water quality information was required by Agriculture Canada in their re-evaluation of registered pesticides across Canada. As a first step in determining what information was needed, it was decided to:

1. evaluate the current situation in the Ontario Region with respect to what water quality information could most effectively contribute to the overall objectives of the National Pesticides Action Plan, and;
2. suggest possible water quality data collection activities which would aid in providing this information.

Methodology:

A contract was let to obtain advice on possible courses of action which could be beneficial to the program.

Results and Discussion:

The contractor's report was completed as scheduled and some preliminary work was started before the end of 1987/88. This work involved letting a small contract to identify a few wetlands areas seen as having high potential for further study in order to assess the impact of pesticide application.

Of the seven possible courses of action recommended by the contractor, three were adopted. These included:

1. The comparison of atrazine and metolachlor runoff from managed (conservative tillage) and unmanaged (conventional tillage) portions of a small watershed in the agricultural heartland of southwestern Ontario.
2. An evaluation of pesticide concentrations in rainfall, and development of a validated sampling methodology.
3. An identification of the potential risk to wetlands adjacent to areas of current pesticide applications.

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2. ATMOSPHERIC LOADING: ATMOSPHERIC TRANSPORT AND DEPOSITION OF TOXAPHENE INTO THE GREAT LAKES ECOSYSTEM - (Dr. E.C. Voldner)

Introduction:

A number of toxic chemicals are transported via the atmosphere to regions remote from their use. Toxaphene, primarily used in the southern United States, has been detected in air and precipitation over the North Atlantic and in the Great Lakes basin. It has been found in fish and water in the Great Lakes and in peat bogs across eastern Canada. It is difficult to quantify the atmospheric input of toxaphene and other toxic chemicals to the Great Lakes and their basins. Previous loading estimates are generally based on a few measurements of pollutant concentrations in ambient air, precipitation, and in the lake water, the former taken either in the basin or in remote areas. Such measurements are then extrapolated temporally and spatially and fluxes computed through various means. The amount of atmospheric loading, its significance relative to other inputs and its important sources, therefore, are generally not known and design of effective control policies and strategies is difficult.

In cooperation with Argonne National Laboratory, the Atmospheric Environment Service has developed a long-range transport model capable of simulating transport, dispersion, and deposition of selected pesticides. Using this aid, the deposition of toxaphene (and other toxic chemicals and nutrients) to the Great Lakes ecosystem was determined and the presence of toxaphene over the North Atlantic was explained. Two periods (1976; 1980) with significantly different use patterns were simulated. Predicted concentrations in air and precipitation compare favourably with measurements.

Objectives:

In this ongoing project, toxic chemicals, priority and emerging, are assessed to determine potential sources of emissions the importance of atmospheric transport, transformation, and deposition to the Great Lakes ecosystem.

Methodology:

To mathematically simulate the atmospheric deposition of toxaphene to the Great Lakes and their basins, the atmospheric pathway of the pesticide from its sources to its sinks must be determined. This requires quantification of emissions and simulation of aerial transport, dispersion, transformation, and removal processes. The model, which is Lagrangian in approach, predicts monthly, seasonal, or multi-year average air concentrations, as well as cumulative wet and dry deposition over spatial scales from about 50 km to continental. Trajectories are initiated every six hours from a site and followed up to seven days. Horizontal dispersion is estimated from plume meandering (i.e., by the mean position and spread of an ensemble of simulated tracer trajectories as a function of plume age for each virtual source). Vertical diffusion is calculated through numerical integration of the standard diffusion equation. Incorporation of nine vertical layers allows slow leakage of pollutants into the free troposphere and permits treatment of emissions from surface sources as well as from tall stacks. Dry deposition including air/surface exchange of vapour (directed upward or downward) is parameterized through the concept of dry deposition velocity. Physical and/or chemical transformation rates are assumed to be linear. Dry deposition velocities, vertical stability profiles and transformation rates vary diurnally and seasonally. Wet removal is assumed to be a function of rain intensity and duration. It is approximated by a power function of the six-hour precipitation rates.

The meteorological data, required for model simulation, were obtained from the Canadian Meteorological Centre (CMC). Continental wind fields, at 100 and 85 kPa levels were obtained with a temporal resolution of six hours and spatial grid resolution of 127 x 127 km^2 from the CMC spectral model. Twenty-four hour objectively analyzed precipitation fields were obtained twice daily with a grid resolution of 127 x 127 km^2. These were apportioned to six-hour intervals.

The model requires information on emission amount as well as time and location of emission. As for most toxic chemicals, little is known about the atmospheric sources of toxaphene. An inventory was compiled from information on use patterns, methods and time of application, predictions from spray models, experimental studies on volatilization, as well as information on residence time and fate in soil.

Results and Discussions:

Analysis of trajectories clearly illustrates the potential exposure of the Great Lakes ecosystem to pollutants in the southern United States. Based on the assumed emission of toxaphene, the model predicted that in 1980 and 1976 approximately 60% of the emitted toxaphene was deposited within North America. The remainder left the continent primarily over the east coast. Transport to the North Atlantic and northern Canada is supported by published measurements from other researchers. Total deposition to each of the five Great Lakes was in the range of 3 to 10 tonnes in 1980. Lake Michigan received the highest input and Lake Ontario the lowest. The average air concentrations over the lakes were below 1 ng/m^3 during early spring and 1 to 2 ng/m^3 during summer.

Although the information on physical and chemical properties, as well as emissions inventories are incomplete and air quality and precipitation chemistry measurements of toxaphene are few and highly uncertain, model predictions show good agreement with the measurements. To improve model-derived estimates of deposition to the Great Lakes, of priority toxic chemicals in general, and toxaphene in particular, it is essential that suitable emission inventories be compiled and information on physical/chemical properties improved. To verify the model predictions, high quality air, precipitation and lake water chemistry measurements are required.

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3. METHODS TO DETERMINE THE TOXICITY, FATE, AND EFFECTS OF PESTICIDES TO STREAM BIOTA - (K.E. Day, J.L. Metcalfe, and S.P. Batchelor)

Introduction:

The contamination of aquatic ecosystems, especially the lotic environment, by non-point source contaminants (e.g., agricultural runoff) has not been well-studied and little is known about the ecological consequences of such contamination. Of particular importance is the evaluation of continuous exposures of stream biota to very low concentrations of contaminants (i.e., the effects of sublethal concentrations).

Objective:

The objective of this study is to develop methods to assess the toxicity, fate, and effects of non-point source contaminants to aquatic invertebrates in riverine environments.

Methodologies:

Several aspects of this study include:

1. Biochemical indicators of stress in stream invertebrates.

The development of biochemical indicators (e.g., changes in concentrations of enzymes, adenylate energy charge, etc.), to determine the effects of contaminants in aquatic ecosystems has two goals: a). to aid in the understanding and prediction of chronic toxicant effects on survival, growth, and reproduction of aquatic organisms; and b). to assess the health of aquatic organisms in situ. Aquatic invertebrates are thought to utilize more energy reserves (i.e., proteins, lipids, and carbohydrates) in order to meet the increased energy demands of exposure to contaminants. There have been suggestions that measuring changes in concentrations of free amino acids in invertebrates is one method of detecting the sublethal effects of such exposure.

In the present study, caged mussels (*Elliptio complanata*) were placed at several sites in the Yamaska River watershed (Quebec) during the summer of 1987 close to sources of agricultural runoff. Caged mussels were also placed in sites considered to be controls (i.e., upstream from sources of contamination). After approximately 30 and 50 days of exposure, mussels were removed from cages at each of the sites, frozen, and returned to the laboratory for analysis of free amino acid levels in the mantle, gills, adductor muscle, and viscera.

2. Bioavailability of pesticides to benthic invertebrates in lotic ecosystems.

Riverine environments contain detritus from allochthonous and autochthonous sources as well as dissolved and colloidal organic matter to which lipophilic contaminants may adsorb. Stream invertebrates ingest, assimilate and egest particulate organic matter thus forming an important link in aquatic food webs by recycling essential nutrients. Little is known, however, about the rates and routes of contaminant accumulation and release by these organisms and the bioavailability of food-adsorbed and suspended sediment-adsorbed pollutants. Laboratory studies were conducted during 1987 to 1988 on the toxicity, uptake, and depuration of several C^{14}-labelled synthetic pyrethroids by two species of caddis flies (Trichoptera).

Results and Discussion:

1. Preliminary comparisons between animals exposed at the various sites indicate that total free amino acids increased in contaminated sites vs a control site after 30 days exposure. Of 11 amino acids detected in mussels; serine, threonine, glycine, valine, proline and alanine were found in the highest concentrations. Glycine and alanine consistently accounted for a significant portion of the total increase in free amino acids.

2. The 48-h LC_{50}s for fenvalerate were found to be 0.662 µg/L for *Chimarra* sp. (Philopotamidae) and 1.901 µg/L for *Hydropsyche* sp. Two other pyrethroids, cyhalothrin and deltamethrin had 48-h LC_{50}s of 0.257 and 0.104 µg/L, respectively for *Hydropsyche* sp. Dissolved organic matter in the form of Aldrich humic acid was found to affect uptake of fenvalerate by *Chimarra* sp. For example, the test organisms accumulated 6.71 (S.D. 2.821) ng/g fenvalerate in filtered water and 2.312 (S.D. 0.392) ng/g fenvalerate in filtered water containing 25 mg/L humic acid.

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4. BIOCONCENTRATION AND BIODEGRADATION OF TRIBUTYLTIN - (Y.K. Chau*, P.T.S. Wong**, D. Liu* and Tian Shizhong***)

Introduction:

Tributyltin (TBT) is mainly used in antifouling paints for boats, ships, and docks, as a lumber preservative, and as a slimicide in cooling towers. Use of tributyltin has been regulated in Canada, but Fisheries and Oceans Canada and Environment Canada have raised concern over recent findings of butyltin species in fish raised in sea pens in British Columbia. The occurrence and toxic effects of tributyltin in oysters have been reported in France and in Canada.

The objective of this study was to determine the bioconcentration of tributyltin by caged mussels in contaminated harbour areas, and in the laboratory with contaminated sediments. Biodegradation of tributyltin in simulated fluvial models was also investigated.

Methodology:

Caged mussel experiments were carried out in Whitby and Oshawa harbours. Parallel experiments were carried out in the laboratory by exposing mussels to contaminated sediments. Biodegradation studies were carried out in the laboratory with cyclone fermentors under aerobic and anaerobic conditions, and various nutrient levels. A gas chromatography - atomic absorption spectrometry (GC-AAS) technique was used for speciation of butyltin compounds in sediment and in mussels.

Results and Discussion:

Laboratory biodegradation of tributyltin using activated sludge inoculum in a cyclone fermentor system followed a dealkylation sequence, giving Bu_2Sn^{2+}, $BuSn^{3+}$, and Sn(IV). Under anaerobic conditions, degradation is more complete as evidenced by the presence of substantial amounts of Sn(IV) in the fermentor solution comparing to only trace amounts under aerobic conditions. In a 26-day experiment, the half-lives of TBT degradation were three and five days for anaerobic and aerobic conditions, respectively. The initial degradation rates were 17%/day for anaerobic conditions and 10%/day for aerobic conditions during the first five days, and levelled off to about 1.2%/day for both systems from day ten onward. Biodegradation of TBT will be studied in a rotating flume to simulate river flow conditions.

Bioconcentration experiments in the laboratory and in harbours are currently in progress.

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s-triazines, Chlorophenols, Chlorinated insecticides

5. QUALITY ASSURANCE IN PESTICIDE ANALYSES - (A.S.Y. Chau and Y. Stokker)

Introduction:

This program coordinates aquatic analytical aspects for the Federal Interdepartmental Committee on Pesticides (FICP).

Results and Discussion:

Quality assurance/quality control studies were conducted on s-triazines, chlorophenols and chlorinated insecticides in natural waters. Results were satisfactory for triazines, but less so for chlorophenols, and the chlorinated insecticide study is in progress. A quality control study on aldicarb and its toxic metabolites aldicarb sulfoxide and aldicarb sulfone showed good agreement between laboratories with high performance liquid chromatographic (HPLC) methods, but poor agreement with gas chromatographic methods. A study on atrazine and neutral herbicides in sediment is in progress. Methods recently developed and submitted to the National Water Quality Laboratory for inclusion in the Inland Waters Directorate (IWD) Analytical Methods Manual are:

- analysis of dinoseb in water by in situ acetylation
- nitrophenols in water
- nitrophenols in sediment
- acid and neutral herbicides in water
- acid and neutral herbicides in sediment
- chlorophenols in sediment

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PESTICIDES PROGRAM IN THE WESTERN AND NORTHERN REGION
(Manitoba, Saskatchewan, Alberta and Northwest Territories)

1. PRELIMINARY STUDY OF THE REGIONAL DISTRIBUTION IN THE ATMOSPHERE OF THE VAPOUR PHASE OF WIDELY-USED PESTICIDES WITHIN WESTERN CANADA - (Dr. S.R. Shewchuk and Mr. K. Wallace)

Introduction:

Each year significant amounts of pesticides are applied to the agricultural lands of western Canada, including approximately 17 x 10^6 kg of herbicides. Pesticide residues are known to enter the atmosphere on dust particles and by volatilization from soil and from water surfaces. Once in the atmosphere they have the potential to travel over great distances as well as to form an unwanted component of the local air mass.

Objectives:

The objectives of the study were to determine if the vapours of commonly used pesticides, including herbicides, insecticides, and fungicides, can be detected in the air mass over an agricultural area of the Canadian west and to compare those values, if detected, with background levels from a site remote from pesticide spraying activity.

Methodology:

Air sampling stations were established near Rock Point, Saskatchewan (in the agricultural area southwest of Saskatoon) and at Cree Lake, Saskatchewan (at a remote northern weather station). The equipment used, technically designated by the name PS-1 PUF (polyurethane foam) sampler, is that approved for pesticide sampling by the United States Environmental Protection Agency (U.S. EPA). Air was drawn through filters containing polyurethane foam and resins, between 1:00 and 2:00 p.m. each day during the months of June to October, 1987. Monthly samples from each site were carefully analyzed using a sequence of procedures including solvent extraction, concentration, gas chromatography and mass spectrum analysis. The analysis sought evidence of the presence of eleven specific pesticides.

Results and Discussion:

Using the instruments and procedures described, no pesticides were found at either site above the detection limits of the system. Those limits range from 0.05 to 2 µg per sample depending on the specific substance involved. Although it is difficult to draw generalizations from these negative findings it is clear that the dispersive power of the atmosphere, particularly during the warmth of midday, is sufficiently great to reduce the ambient concentrations of pesticide vapours below the detection limits of standard sampling systems when operated over months with one-hour-per-day sampling intervals. The project report recommended that future studies focus on the transport of pesticides on dust in the air, continue to monitor and develop an understanding of the atmospheric transport pathway about local application sites and continue to modify and improve sampling instruments and procedures for monitoring pesticides of interest in western Canada.

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7. GROUNDWATER PESTICIDE STUDY: OUTLOOK, SASKATCHEWAN - (D. McNaughton, R. Grover, and W. Nicholaichuk)

Introduction:

This groundwater study, initiated in 1987, focusses on pesticides in groundwater at three sites in the Outlook area, all of which are under irrigation. It is being carried out in conjunction with a surface water pesticide and nutrient balance study, under the direction of the Surface Water Division, National Hydrology Research Institute.

Objectives:

The objectives are:

- to determine whether or not pesticide residues can be detected in groundwater beneath a site where pesticides (herbicides and insecticides) are used regularly; and
- to determine the nature of the processes which lead to the transport of pesticides down through the soil zone.

Methodology:

This is a reconnaissance study, whereby groundwater samples are collected from a number of observation wells, and these samples are submitted to a laboratory to be analyzed for various pesticides. Samples are collected from the observation wells in such a way as to reduce the risk of contamination of the samples. Concentrations of pesticides found in the groundwaters are extremely low, generally less than 1 ppb, so that the sampling procedures are very important.

Results and Discussion:

Since the inception of this study in 1987, some very small concentrations of dicamba and MCPA (Dyvel), diclofop methyl (Hoe Grass), triallate (Avadex BW), and trifluralin (Treflan), have been found in the groundwaters beneath the three sites. The significance of these results is not yet totally clear because the levels observed are so low and there does not appear to be any explanation as to why one type of pesticide is found in an observation well at one time, yet not at another.

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**Aldrin, Endrin, Atrazine,
alpha-Chlordane,gamma-Chlordane,
Heptachlor expoxide, Triallate, Trifluralin**

3. ENHANCED WATER QUALITY MONITORING PROGRAM IN MANITOBA - (Dr. H. Vaughan)

Introduction:

The Water Quality Branch routine monitoring program mostly consists of analysis of water samples for a variety of constituents. Since sediment, fish and macrophytes are known to concentrate many toxic chemicals including pesticides, analysis of these substrates has been undertaken at a number of routine monitoring sites in Manitoba, as this may be more effective at determining presence of pesticides and in assessing the health of the aquatic environment.

Methodology:

Large volume (40 L) water and suspended sediment samples were collected in both the spring and fall at three routine monitoring sites in Manitoba during 1987. The water sample was extracted in the field using a continuous flow-through extractor. Bottom sediment, fish, and macrophytes were collected in the fall. The samples were analyzed for various pesticides in the Water Quality Branch National Laboratory in Burlington, Ontario. In addition, toxicity screening was conducted on sediment and water extracts using nematodes and a number of microbiological bioassay procedures.

Results:

A number of organochlorine insecticides and neutral herbicides were found in extracts of 40-L water samples, including: aldrin, endrin, alpha - and gamma-chlordane, heptachlor epoxide, triallate, trifluralin and atrazine. None of these compounds were found in routine water samples collected at the same time. Analysis of fish, macrophytes and sediment for organochlorine insecticides show few positive detections with DDT compounds being found in fish and one suspended sediment sample having positive endosulfan.

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Triallate, Trifluralin, Diclofop-methyl, Atrazine, 2,4-D, Diallate, Benzoylprop-ethyl

4. METHOD DEVELOPMENT AND ADAPTATION IN THE WATER QUALITY BRANCH PESTICIDE PROGRAM - (J.G. Zakrevsky)

Introduction:

To maintain technical leadership and optimize the effectiveness of the pesticide monitoring and assessment program, the Water Quality Branch is continually evaluating alternate methods for pesticide monitoring. The results may include the adaptation or adoption of new techniques, the initiation or encouragement of directed research, or the testing of newly developed technology within an operational context. In 1987 three such initiatives were continued or undertaken.

1. Field Extraction of Water Samples

Examination of the use of the Goulden continuous flow extractor continued in 1987. The extractor was used to extract 40-L water samples for neutral and acid herbicides analysis and was shown to be workable. Further work is still required to determine partition coefficients to allow better quantification of the results. Through the use of the extractor, low levels of a number of herbicides were identified, including: triallate, trifluralin, diclofop-methyl, atrazine, 2,4-D, diallate, and benzoylprop-ethyl.

2. Evaluation of Compositing Procedures for Pesticide Samples

In order to reduce the high analytical cost of monthly pesticide samples, a program to evaluate the use of compositing sample extracts from monthly samples was started in 1987. Duplicate samples were extracted in the regional laboratory in Saskatoon and the extracts stored and composited over the winter months prior to analysis. The initial results suggest that the approach is workable and little data is lost through compositing. Work is continuing on this program including continued compositing and evaluation of the stability of sample extracts.

3. Broad Spectrum Analysis

The traditional focus of the Water Quality Branch pesticide program has been analysis for target compounds. As a result, much of the information generated in the analysis is lost. The chromatographs are examined only to determine the level of target compounds and any other information on the chromatograph is ignored. Interest in further examination of these chromatographs to assess their relative complexity or make simple comparisons between samples has received considerable attention and has been coined 'Broad Spectrum Analysis'. During 1987, discussions were held on various techniques for examining chromatographs to access some of this lost information, and a two-year feasibility study was initiated. The feasibility study will evaluate the use of broad spectrum analysis and identify areas of additional basic and applied research needed in order to enhance such a monitoring program.

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Lindane, alpha-BHC, 2,4-D, MCPA, MCPB, Atrazine, Picloram, Silvex

5. WATER QUALITY MONITORING OF INTERJURISDICTIONAL WATERS - (Dr. H. Vaughan)

Introduction:

As part of the Federal Government's responsibility with respect to international and interprovincial waters, the Water Quality Branch conducts water quality assessments and monitoring of interjurisdictional rivers throughout the Western and Northern Region. Much of this monitoring is done in support of various boards and committees including the Prairie Provinces Water Board, the International Red River Pollution Board and the East Poplar River Bilateral Committee. As part of this program, samples are collected at selected locations for pesticides analysis.

Methodology:

One-litre water samples are collected at midstream through the vertical depth of the river. Sample collection is for the most part monthly; however, some herbicides are only analyzed in samples collected during the open water period. Samples are sent to the National Water Quality Branch Laboratory in Burlington for analysis. Pesticide analysis included two groups of herbicides and a group of organochlorine insecticides. In total, results are reported for 25 target compounds.

Results:

In 1987, approximately 300 samples were collected for pesticides analysis from 26 sites throughout the regions. The results show that lindane, alpha-BHC and 2,4-D were found in a significant number of samples (25%, 60% and 35%, respectively). The concentration of lindane and alpha-BHC ranged from 0.001 to 0.007 µg/L and 2,4-D was found in concentrations ranging from 0.03 to 0.33 µg/L. Other pesticides found in the water samples but at a much lower frequency (<3%), include: MCPA, MCPB, atrazine, picloram, and silvex. The highest concentrations found for these five pesticides was 0.5 µg/L (atrazine).

Data have been collected for this ongoing monitoring program since the 1970's and collection will continue in 1988. The results are stored in a national data base in Ottawa (NAQUADAT) and are available upon request.

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6. PESTICIDE SURVEY OF SASKATCHEWAN DRINKING WATER SOURCES - (D. Munro)

Introduction:

In cooperation with Saskatchewan Environment and Public Safety, and Agriculture Canada, the Water Quality Branch participated in a survey of municipal drinking water sources in Saskatchewan. The survey, which took place in the fall (1987), was a continuation of Agriculture Canada's monitoring program related to pesticide reevaluation. The Water Quality Branch provided analysis of additional herbicides and quality control for herbicides analyzed by Agriculture Canada through analysis of replicate samples from selected locations.

Methodology:

Raw drinking water samples were collected in late fall by personnel from all three agencies at 43 communities scattered throughout rural Saskatchewan. Eleven of the communities use shallow groundwater wells for their municipal water sources while the remaining communities use surface water from reservoirs, lakes, and sloughs. Samples were analyzed by the Agriculture Canada laboratory in Ottawa and the Water Quality Branch laboratory in Burlington. Agriculture Canada analyzed samples from each location for eight pesticides and the Water Quality Branch laboratory analyzed the samples for seven neutral herbicides. In addition, the Branch analyzed samples from five communities for phenoxy-acid herbicides as a comparison with Agriculture Canada's results. Forty-litre water samples were also collected from three sites and extracted in the field laboratory prior to analysis for neutral herbicides.

Results:

The majority of samples had no positive detections of the herbicides analyzed. However, low levels of triallate, trifluralin, atrazine and 2,4-D were found in at least one sample. All the positive detections were reported in samples analyzed by the Water Quality Branch and were below the detection level (0.5 µg/L) reported by Agriculture Canada. None of the positive detections were found in samples from groundwater sources. The data suggest that for the herbicides tested, there appears to be no major problems for the community water supplies examined. However, the timing of this survey was not ideal as it did not coincide with the application period for most of the compounds tested and as a result may provide a false sense of security in terms of rural Saskatachewan drinking water sources.

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2. STEPHENFIELD RESERVOIR HERBICIDE STUDY - (D. Brown*, V. Chacko**, W. Tibbatts*** and S. Therrien-Richards***)

Introduction:

A preliminary investigation was conducted to study the presence of herbicides in a small, multi-use reservoir in south-central Manitoba, and to determine if the two main inflows into the reservoir were a significant source of transport.

Samples were analyzed at the Water Quality Laboratory in Burlington, Ontario, for phenoxy herbicides (MCPA, MCPB, 2,4-D, 2,4,-DB, 2,4-DP, 2,4,5-T, Silvex, Picloram, Dicamba, 2,3,6-TBA) and neutral herbicides (Trifluralin, Triallate, Diclofop-methyl, Atrazine, Diallate, Barban, Endaven). The objectives of the study were:

1. to determine if fall-applied herbicides are being transported to the reservoir through its stream inflows; and

2. to determine what relationship may exist between heavy precipitation and migration of fall-applied herbicides off site into the reservoir's inflowing streams.

Methodology:

Stephenfield Lake is a multi-use reservoir in south-central Manitoba draining approximately 900 km^2 of predominantly agricultural land. Crops grown are varied and include: cereals, corn, legumes, and pasture.

There are two major inflows into the lake: Roseisle Creek, draining the southern third of the watershed, and the Boyne River, the larger of the two streams, draining north and west of Stephenfield Lake. Each inflow was sampled weekly from September 17 to October 29, 1987. The reservoir itself was sampled once weekly for four weeks, at three sites during the period of study: two on the main body of the reservoir, and one on the Boyne River where it is backed up under the effect of the dam.

After a significant rain event, samples were collected at the Boyne River inflow site every two hours for 36 hours. Four samples were taken from Roseisle Creek every nine hours during this time.

In the spring, the reservoir was sampled again, just before break up, to determine herbicide levels over winter. At first spring melt, Roseisle Creek and the Boyne River were sampled every two to three days over a period of three weeks to determine if pesticides from the fall application were present.

Results and Discussion:

Spring results are still forthcoming. The following discussion relates to fall sampling only.

No neutral herbicides were detected in either of the two inflows, although atrazine was found in six of eight samples collected from the main body of the reservoir (0.2 to 0.4 µg/L). 2,4-D was detected in 13 of 40 total samples, eight in stream inflows (0.03 to 0.10 µg/L) and five at reservoir sites (0.05 to 0.97 µg/L). A trace amount of 2,4,5-T was detected once at the Boyne River, and a trace amount of picloram was detected once at Roseisle Creek.

Of the eight detections of 2,4-D in the stream inflows throughout the sampling program, seven occurred during the intensive sampling following the rain event. All samples taken at the Boyne River during the intitial ten hours of intensive sampling contained 2,4-D at measurable levels. The three initial samples collected at Roseisle Creek after the rain event also contained 2,4-D in steadily decreasing amounts, with none detected in the final fourth sample, or in any of the regular weekly samples at the site.

Conclusions:

Low level pesticide contamination of the reservoir with 2,4-D occurred sporadically. More consistent contamination of the reservoir with the persistent corn herbicide atrazine was found. Fall runoff is not likely to be the main mechanism of transport for this contamination since atrazine was not detected in any stream samples. Following heavy rainfall, 2,4-D contamination was regularly found in the runoff, though no corresponding contamination of the reservoir resulted.

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8. EFFECTS OF DELTAMETHRIN ON PRAIRIE POND INVERTEBRATES AND MALLARD DUCKLINGS - (B.R. Neal*)

Introduction:

Deltamethrin, a synthetic pyrethroid insecticide, is highly toxic to many aquatic invertebrates which are important to the growth and survival of young ducklings. Direct overspraying and significant drift into prairie ponds is likely to occur when deltamethrin is applied by aircraft because it is highly impractical to attempt to avoid spraying ponds when they are scattered throughout cropland. The food supply of young ducklings could therefore be seriously depressed in ponds contaminated by deltamethrin.

The objectives of this project were to:
(a) determine the effects of deltamethrin on invertebrates in prairie ponds; and
(b) compare the growth and survival of mallard ducklings on treated and untreated ponds.

Methodology:

Deltamethrin was applied by aircraft to two ponds at 7.5 grams active ingredient per hectare, the rate registered for control of grasshoppers, fleabeetles, and diamondback moth, on June 17, 1987. Ducklings were maintained on the treated ponds and two untreated control ponds in fenced enclosures where they foraged for invertebrates. Growth and survival of the ducklings were monitored. The invertebrate populations in the four ponds were sampled by emergence traps and benthic cores from two weeks prior to spraying through September, at weekly intervals. Water samples were collected for 12 days following spraying for analysis by Dr. Derek Muir of Fisheries and Oceans Canada, in Winnipeg.

Results and Discussion:

Densities of the populations of chironomid larvae declined by about 50% and 90% during the first six days following treatment of the two experimental ponds, compared to stable or increasing populations in the two control ponds. Invertebrate populations in all treated and control ponds, however, were apparently not sufficient to support the ducklings held in enclosures, because ducklings were dying in all ponds before the spray was applied. The resulting small sample of surviving ducklings precluded comparisons of treatment with control birds. These results differ from those of the trials carried out in 1986, in which invertebrate populations declined after the spray application and duckling growth and survival on treated ponds were less than on control ponds.

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9. ASSESSMENT OF THE EFFECTS OF PESTICIDE USE BY PRAIRIE FARMERS ON THE BURROWING OWL, A THREATENED SPECIES - (P.C. James (contractor)*, G.A. Fox and P. Mineau**)

Introduction:

The Burrowing Owl has been designated as a threatened species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Its limited range and specialized life habits make it vulnerable to insecticides used for grasshopper control. In 1986 and 1987, the Canadian Wildlife Service commissioned field studies to investigate the effects of operational grasshopper spraying on this species in Saskatchewan.

The 1986 investigation of 99 nests on 30 sites near Regina and Val Marie indicated that 76% were exposed to one or more sprayings, and that some were exposed eight times. A total of six insecticides were applied within 400 m of one or more nest burrows; carbofuran (Furadan) and carbaryl (Sevin) each accounted for 35% of the applications. Carbofuran had a significant effect on the survival and reproductive success when sprayed over the nest burrows, carbaryl did not. Effects on reproductive success decreased with decreasing proximity of exposure. The small sample size and *a posteriori* design, which depended upon operational spraying, greatly reduced the ability to detect effects. These results are therefore indicative of a serious problem.

Objectives:

This study was initiated to attempt to elucidate the nature and mechanism of this apparent effect in a much larger sample and to identify other current agricultural practices which may affect the well being of this population.

Methodology:

In 1987, the reproductive activities of Burrowing Owls nesting near Regina and Moose Jaw were monitored. The success and maximum number of young observed above ground at all burrows was determined. Young were trapped, weighed and banded. Insecticide application histories were obtained from the landowner and municipalities. Pellets were collected near the burrows and the food remains they contained were identified. The literature was also reviewed to determine the food habits of this species in Saskatchewan and elsewhere in North America.

In 1986 and 1987, a survey of all landowners responsible for lands on which the study was conducted to: 1. determine the attitude of the landowner toward this species; 2. obtain historical data on the numbers of owls on his land and any major habitat changes associated with his farming practice; and 3. determine the major agricultural practices on the farm in an attempt to identify other widespread practices which may influence Burrowing Owl numbers.

Results:

In 1987, 221 nesting pairs were studied on 69 sites near Regina and Moose Jaw. Grasshopper spraying was greatly reduced in 1987, due to the cool wet weather in April and May and record low grain prices. Spraying only occurred on one farm. Five burrows were oversprayed with carbofuran and two of the pairs disappeared after spraying, an effect consistent with what was observed in the 1986 cases of carbofuran overspray. Our survey of landowners revealed that those who sprayed for grasshoppers in 1985/86 and who had used carbofuran in the past had significantly fewer active nests in 1987 than those who sprayed for grasshoppers in 1985/86 but had never used carbofuran.

The 1454 regurgitated pellets collected during 1986 and 1987 were used to determine the temporal and spatial variation in the owl's consumption of rodents, grasshoppers, and beetles in a year (1986) when grasshopper populations were agronomically significant and when their populations were generally below that necessitating chemical control (1987). In both years there was a decrease in the occurrence of rodents and a concomitant increase in the occurrence of grasshoppers as the summer progressed. A review of 22 studies conducted in 13 states and provinces revealed that the diet of this species in North America includes representatives of two phyla, seven classes, twenty-four orders and over sixty-nine families of animals. Though this species is capable of capturing a wide variety of vertebrate and insect prey and is not dependent upon any single taxonomic group, rodents and insects (grasshoppers and beetles) were utilized in 90% or more of the locations and must be regarded as dietary staples. Although insects are numerically the most abundant prey taken in all areas, they represent a small fraction of the dietary biomass. Two phyla, five classes, nine orders and at least eighteen families of animals have been identified in the diet of Burrowing Owls nesting in Saskatchewan. It is highly unlikely that the temporary elimination, by any insecticide, of the insects and rodents within the home range of a pair of breeding owls would result in a food shortage which would lead to nestling mortality or territorial abandonment, suggesting that the impact of carbofuran was a result of its toxicity not food removal.

All known colony sites in Saskatchewan were partitioned by crop district and their distribution compared to two separate measures of grasshopper infestation. Ninety-eight percent of the Saskatchewan nesting sites occur in crop districts in which grasshopper infestations in 1985-86 potentially needed chemical control. A similar relationship was evident from Alberta and Manitoba data, suggesting that in the three Prairie provinces, the distribution of agronomically significant grasshopper infestations is so similar to the nesting distribution of this owl that no grasshopper insecticide (including carbofuran) can be used without potentially exposing a large proportion of this threatened population.

Our survey of landowners revealed only one other agricultural practice which might have a significant effect on Burrowing Owls. Over 50% of farmers with owls on their land use strychnine to control ground squirrel populations. However, to date we have seen no evidence that this practice affects Burrowing Owls.

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10. TOXICITY OF CARBOFURAN TO SONGBIRDS IN PRAIRIE PASTURES

- (D.J. Forsyth*, C.F. Hinks and N.D. Westcott**, and D.G. Irvine***)

Introduction:

Infestations of grasshoppers in Saskatchewan have resulted in spraying of insecticide over areas totalling, for example, 3 to 4 million hectares in 1985. Most of the spraying occurs during the first three weeks of June, which coincides with the nesting season of many passerines. Grasshoppers are important in the diet of nestling passerines; therefore, the possibility of poisoning exists. In view of the high toxicity of carbofuran, one of the most popular and effective grasshopper insecticides, a study of its effects on songbirds was required.

This project was designed to determine: a). the behaviour of birds towards carbofuran-poisoned grasshoppers; b). the toxicity of poisoned grasshoppers to birds ingesting them; and c). residues of carbofuran in grasshoppers from an aerial application. It is a component of a large-scale field project coordinated by the Toxicology Research Centre, University of Saskatchewan, designed to determine effects of aerially applied carbofuran on upland game birds, raptors, songbirds and small mammals in pasture habitat.

Methodology:

Behavioural and toxicological studies were carried out with twenty Clay-coloured Sparrows (*Spizella pallida*) and five Vesper Sparrows (*Pooecetes gramineus*) captured as nestlings or fledglings and maintained in captivity. In a series of 15-min. choice experiments, individual birds were given equal numbers of dead and live grasshoppers, following 4-h periods of food deprivation. Determinations were made of total quantities of grasshoppers eaten daily by individuals when no other food was available.

Six Clay-coloured Sparrows were given a 1-day supply of 150 grasshoppers that had been sprayed with carbofuran in a spray chamber. Observations were made of bird behaviour, total quantities eaten, and toxic response.

Residues of carbofuran in grasshoppers from a field-spraying operation were determined by analysis of samples collected from 24 transects in a square mile of pasture treated by aircraft at the rate of 140 g active ingredient per hectare. Collections were initiated within an hour of the completion of spraying and were carried out daily for 6 days post-application. Residues were determined by gas-liquid chromatography.

Results and Discussion:

Clay-coloured Sparrows consumed twice the quantity of dead grasshoppers compared to live grasshoppers in the choice experiments. Vesper Sparrows showed some preference for live grasshoppers over dead ones, but of the five birds tested, two ate slightly more dead than live grasshoppers. When Clay-coloured Sparrows were given grasshoppers as the sole source of food for up to eight days, they consumed 8 to 12 g/d, which was equivalent to a mean of 80% of body weight.

Clay-coloured Sparrows given carbofuran-sprayed grasshoppers as the sole source of food for 24 hours consumed the grasshoppers without evidence of taste aversion or toxic effects. Consumption was extended through the 24-h period; therefore, the birds did not receive large doses of carbofuran and were evidently able to metabolize it without showing signs of intoxication. These results agree with observations made in the field after spraying, in that bird populations appeared to be unaffected.

Carbofuran residues in grasshoppers collected 1 to 3 hours after aerial application averaged 2 ppm. This concentration is approximately one half the amount present in fourth instar grasshoppers sprayed in the laboratory spray chamber and fed to the birds.

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11. EFFECTS OF GRASSHOPPER INSECTICIDES ON GROWTH OF NESTLING LOGGERHEAD SHRIKES IN SOUTHERN SASKATCHEWAN - (Wayne C. Harris*)

Introduction:

The Loggerhead Shrike (*Lanius ludovicianus*) has been declining in numbers throughout most of its breeding range in North America for the past 20 years. Populations living on agricultural land in southern Saskatchewan have declined by over 70% in the past 15 years. In 1972, this bird was placed on the National Audubon Society's Blue List of North American birds showing non-cyclical declines, and in 1986 it was designated as threatened in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The decline of shrikes may be due in part to its largely insectivorous diet which results in exposure to insecticides, especially those used for control of grasshoppers.

The aim of this project was to examine the effects of grasshopper insecticides, primarily carbofuran, on the reproductive success of Loggerhead Shrikes in southern Saskatchewan, as measured by clutch size, hatching success, growth of nestlings, fledging success and brain cholinesterase activity in nestlings found dead after spraying.

Methodology:

In each of three areas of southern Saskatchewan, representing infestations of grasshoppers that were expected to be light (Last Mountain Lake), moderate (Courval) and severe (Consul), twenty shrike nests were monitored from June 1 to July 12, 1987. Numbers of eggs laid and nestlings hatched were recorded and measurements of nestling growth were initiated 2 to 5 days after hatching. Weight and length of wing chord, tarsus, and outer primary feather were recorded every five days. Landowners were asked to notify the investigator of their intentions to spray grasshopper insecticides within the feeding territories of nesting pairs. The technique of placing pipe cleaner collars on the necks of nestlings to prevent swallowing of food received from the parents was tested to obtain samples of insects for chemical analysis.

Results and Discussion:

Very little spraying of insecticides occurred, despite relatively heavy infestations of grasshoppers in the Courval and Consul areas, apparently because depressed grain prices made spraying uneconomical. Malathion was sprayed within one feeding territory and dimethoate bran bait was applied within another. In both cases, growth and survival of nestlings was comparable to that of unsprayed sites. The neck collar technique was found to be useful only for obtaining relatively large insects and was potentially lethal to the nestlings. Hatching success, growth, and fledging success data were obtained from 62 nests. These data will provide very useful background information for future studies of insecticide effects and will also be applicable to the management program for shrikes under development within the Threatened Species Section of the Canadian Wildlife Service.

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12. THE EFFECTS OF CARBOFURAN ON MACROINVERTEBRATES IN A PRAIRIE POND - (M. Wayland*)

Introduction:

During the last five years a series of grasshopper outbreaks prompted prairie farmers to protect their crops with a variety of insecticides. The most popular one used was carbofuran, as it was very effective in controlling grasshoppers. With the continuing use of large amounts of carbofuran wildlife and environmental agencies became concerned that the use could have adverse effects on wildlife populations, their food sources and habitat. A series of research projects were developed to assess the potential for environmental damage from the widespread application of carbofuran. The first year of this project was financed with a grant from the Wildlife Toxicology Fund administered by World Wildlife Fund Canada that is supported by Environment Canada. Further work was required to clarify the results observed in the first year's work.

Objectives:

To determine the effects of carbofuran on the benthic macroinvertebrates (ones visible with the unaided eye) in a typical prairie pond.

Methodology:

Watertight enclosures were placed in the pond and then randomly assigned to one of three treatment levels: control (receiving no carbofuran), 5 ppb, and 25 ppb. Watertight enclosures ensured that the introduced chemical would be retained so that the effects on macroinvertebrates could be correlated with the concentration of carbofuran in the water. Macroinvertebrates were sampled within the enclosures on six occasions: twice during the week preceding treatment, and four times during a 55-day interval following treatment. The carbofuran was added to the treatment enclosures and mixed thoroughly as the point of the experiment was to determine the toxicity of different levels of carbofuran to macroinvertebrates and not to simulate a real overspray situation. The bottom samples were sorted in the lab and the macroinvertebrates were picked out, identified, and counted.

Results:

The 5-ppb treatment level did not affect any of the invertebrate groups examined (the scud *Hyallela azteca*, larvae of the midge subfamily *Chironominae*, larvae of the midge subfamily *Tanypodinae*, the snails *Physa* and *Helisoma*, the leech *Helobdella stagnalis*, the mayfly *Caenis* and damselfly nymphs of the family *Coenagrionidae*). The 25-ppb treatment level was highly toxic to *Hyallela azteca* and reduced its abundance and biomass to 10% and 6% of the pre-treatment numbers, respectively. *H. azteca* numbers had almost recovered to pre-treatment levels after 55 days. *Chironominae* larval biomass was reduced to 17% of the pre-treatment levels due to the susceptibility of large *Chironomus* larvae to carbofuran. Small *Chironominae* larvae were not affected to any extent so the abundance did not change significantly. The 25-ppb treatment was not significantly toxic to the other species enumerated.

Discussion:

These results indicate that selected macroinvertebrates are sensitive to carbofuran. The ramifications of this on wildlife populations may be exerted through elimination of important food sources for immature waterfowl, as they gain an important source of protein from bottom-dwelling insects. If the decrease in macroinvertebrate biomass occurred at the same time as increased energy requirements from immature waterfowl, then the impact could be significant.

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13. THE RE-EVALUATION OF IN-USE PESTICIDES - (M. Constable, W. Golebiowski and T. Lambert)

Introduction:

A. **Purpose and Definition of "Re-evaluation".** The following description is from the Agriculture Canada Memorandum to Registrants, R-1-22, May 20, 1986.

Section 19 of the Pest Control Products Regulations provides for the re-evaluation of registered products to "satisfy the Minister (of Agriculture) that the availability of the control product will not lead to an unacceptable risk or harm to things on or in relation to which the control product is intended to be used or public health, plants, animals, or the environment."

Re-evaluation is a review of all registered uses of pesticide active ingredients and the data supporting these uses in the light of current knowledge and concerns. It is a substantially different process from the review and registration of a new product. The purpose of re-evaluation is to: 1. identify and fill data gaps (bringing older data bases up to modern standards); 2. identify and examine concerns regarding human safety or adverse environmental effects; 3. ensure continued efficacy; and 4. take the appropriate regulatory steps to remove those products which are no longer effective or no longer meet the requirements of Section 19.

Re-evaluation determines, in view of identified benefits and risks, whether products can continue to be used safely and effectively, and, if so, the optimum conditions for safe and effective use. Re-evaluation may lead to regulatory changes ranging from minor deletions from product labels, to clarified and/or redefined conditions for use, or when warranted, suspension or cancellation of registered products.

B. **The Role of Environmental Protection, Western and Northern Region.** It is EP's mandate to ensure the protection and preservation of the quality of the environment in the prairie provinces and the Northwest Territories. The objective of the regional office in reviewing pesticides for the re-evaluation program, is to ensure that the priority pesticides do not pose a hazard to the environment with present application practices. Where it is determined that a pesticide may pose a hazard to the environment, the potential hazard will be identified to EP-HQ with recommendations that the concern be addressed by Agriculture Canada through the re-evaluation process. Concerns will be addressed directly by either the manufacturer or by Agriculture Canada. Environmental Protection will do only what is necessary to show that there is reasonable potential for a pesticide to harm the environment. It will be up to the pesticide industry to prove that their products are safe and to refute any information provided to the contrary.

C. **Re-evaluation of Priority Pesticides in the Western and Northern Region.** In a Memorandum to Registrants, R-1-226 of May, 1986, Agriculture Canada announced the order that pesticides will be re-evaluated; 2,4-D and MCPA were both already under re-evaluation. Environmental interest in 2,4-D was low due to its demonstrated low toxicity in use; however, MCPA was less of a known quantity so it was decided that it would be one of the first chemicals reviewed in the region. The group of coal-tar derived antimicrobial wood preservatives (the A-4 Antimicrobials) includes creosote was listed as sixth for re-evaluation. Of the top six groups, EP, W & N Region is interested in two groups, the broad spectrum insecticides (including dimethoate, carbaryl, and carbofuran) and coal-tar derived antimicrobials. Creosote was selected as a regional priority pesticide because of its high sales and high toxicity to aquatic organisms.

Results:

Reviews have been conducted on MCPA, carbaryl, and creosote with reports in preparation. Literature searches and preliminary reviews have been conducted on pentachlorophenol, glyphosate, and dimethoate. These reports are now completed and can be obtained from the contact below.

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PESTICIDES PROGRAM IN THE PACIFIC AND YUKON REGION
(British Columbia and Yukon Territory)

1. ASSESSMENT OF ORGANOTIN CONTAMINATION IN THE BRITISH COLUMBIA ENVIRONMENT - Coastal Salmon Farms and Marinas - (C. Garrett)

Introduction:

Tributyltin (TBT) is widely used as an antifouling agent in marine paints and coatings. Leaching from boat hulls can result in contamination of harbour and marina areas. Preliminary sampling in B.C. harbours by Environmental Protection (EP) indicated that elevated levels of organotin were present in sediments, particularly in the vicinity of shipbuilding/repair facilities. Organotins were also present in fish from Vancouver harbour.

Several B.C. salmon farms have used this compound as an antifouling agent on net pens. Tributyltin is not registered for this use in Canada and, in 1987, Agriculture Canada issued orders to detain all TBT-antifouling products being marketed for use in aquaculture. Studies have indicated that salmon from treated net pens may accumulate TBT.

Tributyltin is among the most toxic of all commercial chemicals released to the aquatic environment and oyster spat have shown especially high sensitivity. Many marinas, active boating areas and salmon farms in B.C. are located in important oyster-growing areas which makes the potential release of TBT from these facilities of particular concern.

Objectives:

The objectives of this study were to determine: the amount and location of TBT usage at B.C. salmon farms; the environmental levels of TBT in the vicinity of farms having used TBT antifoulants; the levels of TBT in salmon reared in TBT-treated net pens; and environmental levels of TBT in the vicinity of B.C. marinas.

Methodology:

Inventory - A questionnaire was circulated to about 100 salmon farms requesting information concerning the amount of TBT product used (Flexguard™); time period used; number of nets treated; and number of nets still in use. Records of net and chemical supply companies were also examined to verify results provided by the salmon farmers.

Environmental Monitoring - Between December 1987 and February 1988, EP conducted sampling at 10 salmon farms, 22 marinas, and 2 control sites to determine levels of organotins and other environmental contaminants in: sediments, water, salmon muscle and liver, and where available, groundfish and shellfish (mussels, clams, and oysters). Analyses were performed by the DFO Great Lakes laboratory in Burlington and the Seakem laboratory in Sydney. Representative samples of all media were split and duplicate analyses were run by both laboratories.

Results and Discussion:

About 30% of the salmon farms surveyed indicated that TBT had been used to treat nets at some time. Several farms reported multiple year usage. At the time of the survey all farms reported that they were no longer treating nets with TBT, although five farms still had treated nets in use. Four farms reported having waste TBT stored on site (total of about 400 to 500 L). The records obtained from the net and chemical supply companies agreed quite closely with the information provided by the salmon farmers.

Salmon Farms - With the exception of fish from one location, organotins were detected in all salmon muscle and liver samples (ng/g wet weight range). Dibutyltin (DBT) levels were below or close to the limits of detection in all salmon muscle samples. In contrast, DBT was present at similar or higher levels than TBT in the liver samples (ng/g wet weight range). TBT was also present at ng/g concentrations in oysters and clams collected in near salmon farms. Oysters contained somewhat higher levels than clams. DBT was also present in oysters collected near salmon farms but at lower levels than TBT. DBT was not detected in clams. With one exception (31 ng/g dry weight), sediment samples collected at salmon farms did not contain detectable levels of TBT. DBT was not detected in any salmon farm sediments. Water samples collected at the salmon farms contained TBT levels ranging from below the detection limit to 63 ng/L. DBT levels were lower and ranged from below detection to 3 ng/L.

Marinas - Organotins were present in biota from almost all marinas sampled. High levels of TBT and DBT (>1 µg/g) have been detected in some shellfish samples collected near marinas. At one location a seasonal variation in organotin levels is suggested. Additional monitoring is planned to determine whether seasonal fluctuations occur. Sediment samples contained organotin levels ranging from below detection to >1 µg/g dry weight. Elevated sediment concentrations at some marinas were reflected in elevated tissue concentrations in local biota. However, at some marinas low concentrations in sediments were detected despite the presence of significant levels in local biota. Organotin levels in water samples varied significantly. Extremely high TBT levels were detected in the Coal Harbour area of Burrard Inlet (up to 2600 ng/L). DBT levels in water samples were generally much lower than TBT levels. Organotin levels in sediments and biota collected from the Coal Harbour area marinas were also elevated. Tributyltin levels detected in water samples are in the range of concentrations shown to cause sublethal effects in laboratory bioassays. Concentrations far exceed the United Kingdom Environmental Quality Target level for TBT (20 ng/L) set by the Department for the Environment for the protection of marine organisms. No similar 'target levels' have been set for Canadian marine waters.

Control Sites - Levels in water, sediments, and shellfish from control sites were below detection.

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2. SURVEY OF CHLOROPHENOL AND DIOXIN CONTAMINATION IN THE ENVIRONMENT NEAR WOOD TREATMENT FACILITIES AND PULP MILLS IN BRITISH COLUMBIA - (C. Garrett)

Introduction:

Accidental release of highly toxic chlorophenols into B.C. waters has resulted in a number of fish kills. Numerous wood treatment facilities in B.C. have utilized chlorophenols for wood protection and preservation; however, the industry is now in the process of converting to alternate antisapstain chemicals. Significant levels of chlorophenols have been detected in effluents, sediments, fish, and surface waters at several B.C. facilities. Dioxins, common contaminants of commercial chlorophenol preparations, enter the environment as chlorophenol releases from wood treatment facilities and during the burning of chlorophenol-contaminated wood wastes. They are also produced in the chlorine bleaching process in pulp mills and from the use of chlorophenol-contaminated wood chips in pulp production.

Sampling conducted by Environmental Protection (EP) and the Canadian Wildlife Service (CWS) in 1983 near B.C. wood treatment facilities confirmed the presence of dioxins in fish tissue and heron eggs. Existing information was not adequate for assessing the extent of contamination or the potential environmental impact. Further data are required on the ambient levels of chlorophenols, and dioxins and furans which are associated with the chlorophenol formulations used in the region.

The objectives of the study were to determine levels of: chlorophenols, chlorinated anisoles, chlorinated dibenzodioxins and chlorinated dibenzofurans in sediments, water, aquatic biota, and heron eggs near selected wood treatment facilities and pulp mills in B.C.; and the precision and accuracy of analytical results by conducting interlaboratory comparisons using split, duplicate, and spiked samples.

Methodology:

Sediment, fish, invertebrate, heron egg, and water samples were taken near B.C. wood treatment facilities and pulp mills by EP, CWS, and Inland Water/Lands (IW/L). Samples were analyzed for chlorophenols, chlorinated anisoles, chlorinated dibenzodioxins, and chlorinated dibenzofurans. Select samples are being analyzed for metals and PCBs.

Results and Discussion:

Significant levels of dioxins and furans are present in the receiving environment of specific sawmills and pulp mills in B.C. The source of contamination at sawmills is chlorophenate antisapstain chemicals used for wood treatment. These chemicals are contaminated with significant levels of the higher chlorinated dioxins and furans reflected by the very high levels of their isomers in the receiving environment of some sawmills. The sources of dioxin/furan release from pulp mills include the: production of 2,3,7,8-TCDD/F in the chlorine bleach process; use of chlorophenol-contaminated wood chips in the pulping process; and possible production of dioxins in the process. Four B.C. pulp mills at Howe Sound, Crofton, and Prince Rupert have been identified as priority sites requiring further study. This study mainly concerns marine pulp mills; however, environmental samples from freshwater pulp mills should also be analyzed.

Sediments - Dioxins - H6CDD, H7CDD, and OCDD had the highest concentrations at all sites. In sediments collected off pulp mills, H6CDD predominates, but in sawmill samples H7CDD and OCDD are usually higher. Total PCDD levels up to 53 814 ppt were detected in the sawmill sediments, and up to 19 266 ppt from pulp mills. 2,3,7,8-TCDD was present in samples collected at all pulp mill outfalls; the source of which was unknown. Furans - 2,3,7,8-TCDF was detected in sediments at all pulp mill outfalls and off most sawmills sampled. TCDFs make up at least one half of the total PCDFs present in the sediments. In contrast, at sawmills H6CDF, H7CDF, and OCDF account for most of the total PCDF present.. The furans, particularly H6CDF and H7CDF were present at levels higher or comparable to the corresponding dioxins. With the exception of TCDFs, furans were usually present at much lower levels than the corresponding dioxins at the pulp mills. Detection of higher chlorinated dioxins and furans at sawmills is expected because of their significant concentrations in chlorophenate antisapstains. Presence near pulp mills is probably associated with use of chlorophenol-contaminated chips. All mills sampled have used contaminated chip supplies; however, the higher chlorinated furans are present at much lower levels than the dioxins indicating that the use of contaminated chips results in a greater release of higher chlorinated dioxins than furans. This cannot be explained by the relative levels of dioxins and furans in the chlorophenate formulations. It is possible that higher chlorinated dioxins are being formed in the process.

Aquatic Biota - Dioxins - H6CDDs were detected most frequently with highest concentrations in biota samples. The TCDD and H6CDD isomer distributions in sediments and biota were similar. Although in sediments OCDD and H7CDDs were detected at proportionately much higher levels than in biota. Crab hepatopancreas contained higher levels and more isomers of dioxins than other biological tissues analyzed. High levels of 2,3,7,8-TCDD were detected in the hepatopancreas of crabs collected near some mills; and H6CDD was present at higher concentrations. Crab muscle tissue contained much lower concentrations of dioxins and fewer isomers than the hepatopancreas. However, significant levels of 2,3,7,8-TCDD were present in crabs from two mills (12 and 14 ppt) and up to 117 ppt H6CDD was detected in crab muscle. Distribution patterns for PCDD isomers in mussels, oysters, and clams were similar to those seen in crab hepatopancreas but concentrations were much lower. However, at one mill high levels of 2,3,7,8-TCDD were detected in oysters which at one location exceeded the tolerance level. The highest concentration occurred in oysters collected nearest the mill and levels decreased with distance from the mill. Prawns were also a good indicator species for dioxins. Levels in sculpin and other finfish species whole body tissues were generally low and in fillet samples were very low or non-detectable. Furans - TCDFs were the predominant isomers detected and, with the exception of crab hepatopancreas, the higher chlorinated isomers were generally not present or were present at very low levels. The 2,3,7,8-TCDF levels in biota were much higher than the 2,3,7,8-TCDD levels. Very high levels of 2,3,7,8-TCDF were detected in crab hepatopancreas. Significant levels of 2,3,7,8-TCDF were also detected in crab muscle, prawns, and oysters. With the exception of a few samples, 2,3,7,8-TCDF levels in fish ranged from 4 to 20 ppt.

Heron Eggs - Significant levels of dioxins/furans were detected in the heron eggs of several colonies in the southern coastal areas of B.C. The highest concentrations were present in the Crofton area colony which feeds in the vicinity of a kraft pulp mill outfall. A threefold increase in 2,3,7,8-TCDD levels between 1986 and 1987 were observed in this colony. The heron egg data is discussed in detail in the Canadian Wildlife Service Progress Note No. 176 (April, 1988).

Chlorophenols and Other Contaminants - Analysis for these environmental contaminants is not yet complete.

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3. DIOXINS IN THE ENVIRONMENT NEAR WOOD TREATMENT FACILITIES IN BRITISH COLUMBIA - (R. Norstrom and J. Elliot*; P. Whitehead and R. Butler**)

Introduction:

Dioxins (PCDDs) and furans (PCDFs) are a group of environmental contaminants of considerable concern. These classes of chemicals (there are 75 CDDs and 135 CDFs) are formed as by-products in the manufacture of other chlorinated organics, such as the chlorophenols and PCBs and are highly persistent in the environment. Large amounts of chlorophenols are used in British Columbia as fungicides to prevent staining of lumber. It was recently discovered that TCDD and TCDF are produced in the chlorine bleaching process to kraft pulp mills. Some of these chemicals, in particular 2,3,7,8-TCDD, have extreme acute and chronic toxicity and have been shown to be lethal to chicken embryos at the several hundred parts-per-trillion level. Great Blue Herons in several areas of B.C. contain potentially embryotoxic levels of hexachloro-, pentachloro- and tetrachloro-dioxins.

Objectives:

The objectives of this study were to determine sources of PCDDs and PCDFs found in the Strait of Georgia and effects on wildlife, especially resident fish-eating birds such as the Great Blue Heron.

Methodology:

Five Great Blue Heron colonies in the Strait of Georgia area were studied: at Crofton, 1 km from a kraft pulp mill; on Gabriola Island near the kraft pulp mill; on the endowment lands of the University of British Columbia; on the Nicomekl River in an agricultural setting; and at Sidney Island in an area not receiving any direct input of industrial wastes.

Eggs were collected from nests at each colony and shipped to the Canadian Wildlife Service (CWS) National Wildlife Research Centre (NWRC), where they were analyzed for PCDDs, PCDFs, PCBs, organochlorine pesticides and mercury. Number of young fledged in nests from which eggs were taken and in undisturbed nests was measured. In addition, samples of heron prey species and other fish and invertebrate samples were collected at the same and other sites around the Strait of Georgia and analyzed.

Results and Discussion:

Elliot et al. (1988) describe the results of studies to date on levels and possible effects of PCDDs and PCDFs in Great Blue Herons. The study shows that there is widespread contamination by PCDDs and PCDFs of the Great Blue Herons feeding in estuarine and coastal areas of the southern Strait of Georgia.

Eggs from the colony at Crofton contained the highest levels of contamination, but levels of some PCDDs at the least contaminated colonies at Nicomekl and Sidney Island were still significantly higher than levels found in eggs of fish-eating birds in other parts of Canada, including the Great Lakes. There appears to be a unique source(s) of PCDD's in the aquatic environment in B.C.; the most important potential source being chlorophenols. About 700 t of chlorophenols are used annually by the B.C. forest industry and studies have shown that receiving waters near B.C. sawmills are often contaminated with chlorophenols. Kraft pulp and paper mills are known to produce 2,3,7,8-TCDD and 2,3,7,8-TCDF during the chlorine bleaching process. Because the Crofton heron colony is feeding near the outfall of the mill, it is probable that this is the main source of 2,3,7,8-TCDD in heron eggs at that location.

In 1987, the colony at Crofton failed to produce any young and mean 2,3,7,8-TCDD levels in eggs were three times those of 1986. Whether the sharp increase in 2,3,7,8-TCDD levels precipitated the failure of the colony to fledge young is uncertain. The overall fledging success of Great Blue Herons in southern B.C. has declined during the past ten years. Detailed studies are underway in cooperation with researchers at the University of British Columbia to further investigate the possible effects of PCDD and PCDF contamination on the breeding success of Great Blue Herons.

Preliminary comparison of PCDD and PCDF levels in sediments, fish, and in particular crabs, which are excellent indicators of environmental levels of this class of compounds, indicates that chlorophenols are probably the main source of the higher chlorinated dioxins in the B.C. environment, while kraft pulp mills are probably more important sources of the tetrachloro-dioxins and furans.

Reference:

Elliott, J.E., R.W. Butler, R.J. Norstrom, and P.E. Whitehead, Levels of Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans in Eggs of Great Blue Herons (*Ardea herodias*) in British Columbia, 1983-87: Possible Impacts on Reproductive Success, Canadian Wildlife Service Progress Note No. 176, 7 pp. (1988).

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4. GROUNDWATER PESTICIDE STUDY: ABBOTSFORD, BRITISH COLUMBIA - (D. McNaughton)

Introduction:

This groundwater study was initiated in 1984, by the National Hydrology Research Institute in Vancouver, British Columbia. The study focusses on pesticides in groundwater within the Abbotsford Outwash aquifer, which is an extensive, highly permeable aquifer used for water supply to Abbotsford and Clearbrook, as well as for domestic supply for a large number of homes in the surrounding area. This area is intensively cultivated for fruit crops, and there is heavy pesticide and fertilizer usage as a result. Many farms are irrigated, and the annual precipitation is quite high, causing pesticides applied on the land to wash down into the groundwater zone more easily than in a more arid, dryland farming situation.

Objectives:

The objectives of the study were:

- to determine whether or not pesticide residues can be detected in groundwater sampled from the Abbotsford aquifer; and
- to relate the results to existing hydrogeological and hydrochemical information, to determine if there is any water quality problem as a result of pesticides in the groundwater.

Methodology:

This is a reconnaissance study, whereby groundwater samples are collected from a number of observation wells, and are submitted to a laboratory to be analyzed for various pesticides. Samples are carefully collected from the observation wells to reduce the risk of contamination. The initial phases of the study consisted of the sampling of various water wells throughout the area. These samples were analyzed for various pesticides, by a private sector laboratory. The second phase of the study concentrated on a broader list of pesticides, again using domestic wells as sampling points. The results of this study turned up detectable levels of some organonitrogen and organophosphorus pesticides in the water. The third phase of the study, still underway, consisted of a small drilling program, during which six observation wells were drilled. These were sampled in August, 1988.

Generally, the concentrations of pesticides detected are less than one part per billion, so that during sampling it is very important to minimize the risk of sample contamination.

Results and Discussion:

Since the inception of this study, some very low concentrations of various organonitrogen, organophosphorus, and organochlorine pesticides and their residues have been detected in domestic wells. Because they are at such extremely low concentrations, however, there is no telling at this time whether this constitutes an environmental and/or health problem. The concentrations detected have at all times been below the existing federal government guidelines for drinking water quality.

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5. GROUNDWATER PESTICIDE STUDY: OSOYOOS, BRITISH COLUMBIA - (D. McNaughton)

Introduction:

This is a groundwater study which was initiated in 1984, by the National Hydrology Research Institute in Vancouver, British Columbia. The study focusses on pesticides in groundwater within the Osoyoos aquifer, which is an extensive, highly permeable alluvial aquifer used for water supply to Osoyoos and the surrounding area. The area is intensively cultivated for fruit crops, and there is heavy pesticide and fertilizer usage as a result. All farms in the area are irrigated, and this facilitates the downward leaching of pesticides applied on the land.

Objectives:

The objectives of this study were:

- to determine whether or not pesticide residues can be detected in groundwater sampled from the Osoyoos aquifer; and
- to relate the results to existing hydrogeological, hydrochemical, and land use information, in order to determine if there is any water quality problem as a result of pesticides in the groundwater.

Methodology:

This is a reconnaissance study, whereby groundwater samples were collected in 1984 from a number of observation and domestic wells, and submitted to a laboratory to be analyzed for various pesticides. Samples were collected in such a way as to reduce the risk of their contamination.

In 1987 a more extensive survey was conducted, and the observation wells were re-sampled. In addition to the sampling survey in 1987, a study was conducted into the rate of groundwater flow into Lake Osoyoos through the lake bottom.

Since the latest sampling survey was completed in 1987, there have been no specific plans made for the continuation of the study.

Results and Discussion:

Since the inception of this study, some very low concentrations of various organonitrogen, organophosphorus, and organochlorine pesticides and their residues have been detected in domestic wells. Because they are at such extremely low concentrations, there is no telling at this time whether this constitutes an environmental and/or health problem. The concentrations detected have at all times been below the existing federal government guidelines for drinking water quality.

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6. LEVELS OF SELECTED PESTICIDES IN FARM DITCHES LEADING TO RIVERS IN THE LOWER MAINLAND OF BRITISH COLUMBIA - (M.T. Wan)

Introduction:

A three-year survey was initiated to determine residue levels of the more commonly used agricultural pesticides (azinphosmethyl, diazinon, dinoseb, endosulfan, and fensulfothion) in selected farm ditches leading to the fishery sensitive Fraser, Nicomekl, and Sumas rivers.

The main objective of this study was to evaluate the potential effects on aquatic invertebrates and Pacific salmonids of pesticide residues in ditches before they are transported to major rivers.

Methodology:

Sediment and water samples were taken at random from ditches at five study sites. The study sites where:

1). similar crops were grown (e.g., beans, broccoli, cabbage, corn, onions, peas, potatoes, strawberries);

2). dinoseb was used as a top killer in early May and mid June, and azinphosmethyl, diazinon, endosulfan, and fensulfothion, as insecticides in July and August;

3). farm ditches were leading either singly or collectively to the Fraser, Nicomekl, and Sumas rivers;

4). crop setbacks from ditches were 3 m or less; and

5). ditches with water averaged about 1.5-m wide and 0.5-m deep.

Results and Discussion:

In 1985, azinphosmethyl, diazinon, endosulfan, and fensulfothion were not found at a detection limit of 1 µg/L in the ditch water at any of the study sites. Dinoseb was, however, consistently found in ditch water of four study sites, and the mean level was 4.9 µg/L (range, 0.3 to 18.6 µg/L).

In the fall of 1986, dinoseb was detected only once (5.0 µg/L) at one study site. Although endosulfan residues were not detected in water in 1985, this insecticide was found once in 1986 shortly after treatment (i.e., 0.5 h) at one site. The mean level was 1530 µg/L $\pm$ 476 (S.E.).

In 1985, low levels of azinphosmethyl, diazinon, dinoseb, endosulfan, and fensulfothion residues ranging from 2 to 10 µg/kg were found in ditch sediments at two study sites. However, endosulfan residues were consistently found in the ditch sediments at five sites. The mean concentration was 18.8 µg/kg (range, 2 to 150 µg/kg).

In 1987, both dinoseb and endosulfan residues were found in the ditch sediments at two additional study sites. The residue levels ranged from 135 to 652 µg/kg.

Conclusions:

Azinphosmethyl, diazinon, dinoseb, endosulfan, and fensulfothion residues were detected in ditches leading to the Fraser, Nicomekl, and Sumas rivers of British Columbia. The levels of these pesticides in water and sediments varied but appeared to be elevated during high seasonal rainfall. There was evidence that the levels of pesticides in ditch water shortly after application exceed the 96-h LC_{50} values of fish and aquatic invertebrates, e.g., endosulfan. The effect on salmonids and aquatic invertebrates of low levels of pesticides in water and sediments is presently not known.

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7. EVALUATION OF ACUTE TOXICITY TO JUVENILE PACIFIC SALMONIDS OF HEXAZINONE AND ITS FORMULATED PRODUCTS: PRONONE 10G, VELPAR® L, AND THEIR CARRIERS - (M.T. Wan, D.J. Moul, and R.G. Watts)

Introduction:

Hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl 1,3,5-triazine-2,4(1H,3H)-dione] is a broad spectrum herbicide manufactured by E.I. du Pont de Nemours & Company. Its formulated products, Pronone 10G and Velpar® L, are non-selective herbicides used for vegetation control. The use of these herbicides for brush control in coastal British Columbia forests may result in the introduction of hexazinone into waterbodies inhabited by salmonid fish.

The objective of this study was to assess the acute toxicity of hexazinone and its formulated products and their carriers to juvenile Pacific salmonids.

Results and Discussion:

Hexazinone (96-h LC_{50}, 276 mg/L) is significantly more toxic to salmonids than its formulated products Pronone 10G and Velpar® L with respective 96-h LC_{50}'s of 1686 mg/L and 904 mg/L. The results suggest that the carriers in these two products are of low toxicity to juvenile salmonids.

Within species, the order of increasing toxicity of hexazinone to salmonids is: chinook, sockeye, chum, rainbow trout, coho and pink. For Velpar® L, toxicity increased by species as follows: chinook, chum, sockeye, coho salmon, rainbow trout, and pink salmon.

Although hexazinone is not as highly toxic as triclopyr ester herbicide to juvenile Pacific salmonids (96-h LC_{50} of 0.7 mg/L), it nonetheless may have indirect effects on the fish. When applied at the registered rate of 4.0 kg active ingredient per hectare, hexazinone persisted in the boreal environment for more than 500 days.

At the same rate of application, hexazinone has affected vegetation beyond the site of application (up to 100 metres offsite) because of its mobility in soils and surface run-off. This herbicide, therefore, has the potential to affect stream-side vegetation and possibly destroy important salmon habitat.

Conclusions:

This bioassay study indicates that hexazinone is toxic to juvenile Pacific salmonids. This herbicide is more toxic to the same fish species than its formulated products: Pronone 10G and Velpar® L. The carriers of both products are of low toxicity to the salmonids, and they appear to reduce the toxicity of hexazinone in the formulated materials. The toxic effect to young salmon of hexazinone transformation products is presently not known. However, due to its mobility and persistence, hexazinone has the potential to destroy riparian vegetation of salmon habitat.

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PESTICIDES PROGRAM AT THE NATIONAL WILDLIFE RESEARCH CENTRE (NWRC) HULL, QUEBEC

1. A GENERIC REVIEW OF SEED DRESSINGS AS A HAZARD TO BIRDS AND OTHER WILDLIFE - (G.A. Fox)

Introduction:

Pesticide-coated seeds, like insecticide granules, are highly concentrated "packages" of toxic chemicals which are readily consumed by birds and other wildlife if left on the soil surface after the seeding operation. Since the early 1960s, the best documented kills of birds in Great Britain, Europe and the United States have been due to seed dressings. In 1985, an estimated 3 000 000 ha of lindane-treated canola and wheat, alone, were sown in the three prairie provinces. There is, therefore, a great potential for exposure of migratory birds that arrive to breed near, or are crossing the prairies at this time. The migratory birds frequently forage and roost in these fields.

Objectives:

The objectives of this study were:

1. to obtain and review the existing literature and unpublished reports documenting the major wildlife problems associated with the use of mercurial, cyclodiene, organophosphate, carbamate and other seed dressings since the mid-1950s;

2. to identify the species at risk, the conditions resulting in the exposure, the nature of the toxicity and other factors contributing to the hazard; and

3. to incorporate these findings into an evaluation protocol for seed dressings and into environmental toxicology guidelines as they are developed.

Methodology:

Existing literature and unpublished reports related to the hazards of seed dressings to birds and other wildlife were obtained and reviewed. In addition, the agricultural literature was searched for information on the efficiency of seed incorporation of machinery used in prairie agriculture today.

Results and Discussion:

An extensive documentation of the hazards and problems associated with the use of mercurial, cylcodiene, organophosphate, carbamate and other seed dressings in the northern hemisphere has been obtained and some of it reviewed. Preliminary analysis of these reports indicates:

1. that when available, dressed seed is consumed by a wide variety of bird species and that mortality and secondary poisoning of birds of prey may result, depending on the toxicity of the active ingredient; and

2. exposure (the availability of treated seed on the soil surface) is clearly the most important variable affecting hazard. The only data located for the efficiency of incorporation of cereals comes from Britain in the 1960s and early 1970s, and from Sweden in 1965. The machinery used is not at all comparable to what is used today on the prairies.

In evaluating the hazard posed by new and existing formulations for these uses, it is only possible to determine how many seeds are necessary to kill a bird or small mammal, since there is no relevant measure of seed availability. Obviously, some degree of incorporation is necessary for satisfactory yield; however, this level may fall short of what is required for wildlife protection.

This project is on-going. Future efforts will focus on obtaining estimates of seed incorporation efficiency under current agronomic practices in the Canadian prairies. When this information is obtained, the hazard evaluation will be completed and publications and evaluation protocols written.

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2. A REVIEW OF GRANULAR INSECTICIDES IN USE IN CANADA AND THEIR HAZARD TO BIRDS - (P. Mineau and B.T. Collins)

Introduction:

Granular formulations of insecticides are widely used in Canada, often over very large areas. Each granule contains a relatively large quantity of active ingredient and birds and other wildlife are exposed to these granules in various ways and indeed appear to pick up poorly incorporated granules. Numerous cases of poisonings have been reported in Canada as well as in other countries.

Objectives:

The objective of this project was to review the evidence and data available in Canada or relevant to the Canadian situation so that a strategy and/or corrective measures could be put in place to assess and reduce the severity of this problem.

Methodology:

A number of sources of information were used in order to arrive at a hazard scenario:

1). use pattern information available from pesticide labels and provincial advice to growers;

2). use quantity information available from various farm and registrant surveys;

3). unpublished records of kills from federal and provincial authorities as well as from diagnostic veterinary centres;

4). registrant studies on supervised field applications; and

5). open literature information on kill incidents and on agronomic aspects of granular use.

Results and Discussion:

Highlights of the analysis are to be published in the proceedings of a conference titled: Field Methods for the Study of Environmental Effects of Pesticides, sponsored by the British Crop Council and held in Cambridge, England (March, 1988).

In summary, two granular use patterns should be given priority consideration, on account of their extent of use and possible consequences to wildlife populations: the use against flea-beetles in canola (rape seed) in western Canada; and the use in corn in southern Ontario.

Treatment of canola for flea-beetles comes at a time when large numbers of arctic-nesting songbirds pass through the prairies. A large kill of Lapland Longspurs has already been reported but there seems to be some question as to whether this represented a case of the farmer not using the product correctly. As a result of the risk analysis, a contract has been let to the Alberta Farm Machinery Research Centre to investigate the efficiency with which different types of farm machinery used in prairie agriculture incorporate granules into the soil.

The use of insecticide granules to control corn rootworm represents the other major use of granular formulations in Canada. Based on studies carried out in the United States under conditions similar to those in Ontario, and, on the use of corn granulars in that province, the resulting direct bird kill is conservatively estimated at 0.2 to 1 million from 1980 to 1985. Most of these birds would be breeding individuals of small granivorous or insectivorous songbirds. Secondary kills of scavengers are also thought to be common.

Evidence from the literature and computer simulation modelling suggest that kills are not likely to come to light following casual monitoring of fields. (This analysis is also to be published in the proceedings of the same conference). A lack of reported kills for Ontario therefore in no way refutes the kill estimates previously presented.

It appears that some level of mortality is inevitable given the agricultural machinery available today and the high toxicity of granulars favoured by growers. In view of the scale of the wildlife mortality thought to be taking place, at least in corn fields, there are grounds for closely examining the agronomic necessity of these formulations and to replace them whenever possible by less damaging products.

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3. A REVIEW OF DIAZINON RESIDUES FOLLOWING ITS USE ON TURFGRASS - (P. Mineau)

Introduction:

The use of diazinon on turf, applied either as a liquid or as granules is known to give rise to bird mortalities, principally waterfowl which are attracted to and graze on turfgrass. These mortalities are thought to be frequent, generally unreported, and in some cases, extensive. For example, an estimated 700 Brant Geese died following a single application of diazinon to a golf course in New York State.

Because a large proportion of the casualties are migratory waterfowl of Canadian origin and because this issue represents an important test case for wildlife protection, the Canadian Wildlife Service has been cooperating closely with the United States Environmental Protection Agency (U.S. EPA) in assembling the best case possible in response to a Court challenge by the manufacturer.

Objectives:

Because it has been proposed that lowering the application rate would alleviate wildlife problems, the issue of grass residues resulting from application at various rates is important.

The main contribution of the Canadian Wildlife Service to the overall case was a stringent analysis of all the data available on residue levels measured in turfgrass and other environmental matrices in order to calculate the hazard to grazing birds.

Methodology:

All possible sources of data were used. The bulk of the information was extracted from unpublished company studies. In most cases, raw data were re-analyzed because serious methodological errors were uncovered.

Results and Discussion:

Results of the analysis were detailed in a report which was entered as expert testimony in U.S. Federal Court.

Available data indicated that the lowest proposed rates (experimental rates far below those currently stipulated on U.S. or Canadian labels) were still high enough to give rise to lethal grass residues (subsequent mortalities during field tests indicated that this interpretation was accurate) and that diazinon could not be used safely in turfgrass at rates that are still efficacious.

As a result of this and other testimonies, diazinon has now been withdrawn from use on golf courses and sod farms in the United States. Other turfed sites are currently under investigation for hazard to waterfowl as well as to songbirds which may feed on contaminated invertebrates.

The full extent of waterfowl mortality resulting from the use of diazinon in Canada is not known. Kills have so far been reported in B.C. and Ontario. The frequency of kills in Canada may be less than in the U.S. by virtue of our climate, the migratory patterns of waterfowl, and pest infestation levels. The Canadian Wildlife Service is attempting to obtain more information on these factors.

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4. TOXIC EFFECTS OF ORGANOPHOSPHATE AND CARBAMATE PESTICIDES ON BIRDS - (S. Kennedy and S. Trudeau)

Introduction:

Organophosphate and carbamate pesticides are potent anticholinesterase substances that are used extensively by the agricultural and forestry industries. Their use in wildlife habitats has been responsible for the deaths of large numbers of birds. Cause of death in such kills is generally diagnosed by measuring brain cholinesterase (ChE) activity. Sublethal exposure to organophosphate and carbamate pesticides is assessed by measuring plasma ChE activity which is considerably easier and less expensive than measuring pesticide residue levels. The ChE methods that were used at the National Wildlife Research Centre (NWRC) before this project, however, were not able to discriminate between organophosphate and carbamate poisonings, and required the freezing of plasma samples in the field.

Objectives:

The objectives of this study were: 1. to set up and evaluate the usefulness of a cholinesterase method used in Britain (Martin et al., Bull. Environ. Contam. Tox., 26, 775 (1981)) to discriminate between organophosphate and carbamate-induced cholinesterase inhibition in bird brains; 2. to develop a method to store avian blood on filter paper for subsequent cholinesterase activity measurements, and to assess its potential application for collecting samples of bird blood in the field; and 3. to carry out cholinesterase analysis on field-collected samples of bird brains and plasma.

Methodology:

1. Gel Filtration/2-PAM Reactivation. Martin et al. (1981) showed that bird poisonings from organophosphates can sometimes be distinguished from those caused by carbamates by comparing the effects of gel filtration and pyridine-2-aldoxime (2-PAM) on the reactivation of brain ChE activity (as measured by the Ellman method, Biochem, Pharmacol. 7, 88 (1961)). Gel filtration reactivates carbamate-inhibited ChE quickly, but does not reactivate (or reactivates slowly) organophosphate-inhibited ChE. Conversely, 2-PAM sometimes reactivates organophosphate-inhibited ChE, but not carbamate-inhibited ChE. Minor modifications were made to the methods of Martin et al. (1981) to facilitate the analysis of brain and plasma ChE activity under the same reaction conditions. These methods were applied to the analysis of brain and plasma ChE of Japanese Quail dosed with diazinon and chlorpyrifos (organophosphates) and carbofuran (a carbamate). The results of these experiments were used to assess the potential routine application of the methods at NWRC.

2. Filter Paper Storage of Bird Blood. The blood of control Japanese Quail and those dosed with chlorpyrifos and carbofuran was collected upon sacrifice of the birds. Plasma was obtained (by centrifugation) and frozen, and aliquots (20 to 50 µL) of whole blood from each bird was spotted onto small discs of filter paper. When the blood was dry, the filter paper discs were stored under several conditions (e.g., left at room temperature for several days before freezing; refrigerated for several days before freezing; frozen immediately, etc.). At several time points after blood collection, water was used to elute a fraction of ChE bound to the filter paper discs, and ChE activity was measured as described by Eriksson and Faijersson (Clin. Chim. Acta., 100,165 (1980). Comparisons were made between ChE activities in the filter paper eluates and ChE activities in the frozen plasma (Ellman method). The results were used to assess the potential field application of the filter paper storage technique.

3. ChE Activity in Field-collected Samples of Bird Brain and Plasma. Here the Ellman method was used for: 1. Brain: Canada Geese (22); Peregrine Falcons (1); American Kestrels (2); Mourning Doves (1); and 2. Plasma: Long-eared Owls (2); Sharp-shinned Hawks (17); American Kestrels (2); Red-tailed Hawks.

Results and Discussion:

1. Gel Filtration/2-PAM Reactivation. The findings of Martin et al. (1981) were confirmed. Carbofuran-inhibited plasma and brain ChE activity was reactivated by gel filtration, but not with 2-PAM. In contrast, chlorpyrifos-inhibited plasma and brain ChE was not reactivated upon gel filtration, but was with 2-PAM. Diazinon-inhibited ChE was not reactivated as much with 2-PAM as was chlorpyrifos-inhibited ChE, but the results were what was expected for an organophosphate, not a carbamate (i.e., some reactivation with 2-PAM, but no reactivation upon gel filtration). This method can help distinguish between bird kills caused by organophosphates and those caused by carbamates. The technique is easy to carry out, and can now be applied routinely at NWRC for field-collected samples of birds suspected of pesticide exposure. However, the results of several groups (and some preliminary results of our own) show that the technique will not always work. It cannot replace chemical residue analysis. Results from this simple test, however, can suggest whether organophosphate or carbamate residue analysis should be done.

2. Filter Paper Storage of Bird Blood. Results showed that Japanese Quail blood ChE is extremely stable on filter paper. The activity of normal ChE and carbofuran and chlorpyrifos-inhibited ChE remained constant for several months after collection under all storage conditions. Unfortunately, the degree of ChE inhibition caused by the two pesticides was substantially lower than that measured in frozen plasma. The technique, therefore, has the risk of producing false negatives and is not ready for field testing.

3. ChE Activity in Field-collected Samples of Bird Brain and Plasma. In our laboratory the normal activity of brain ChE in Canada Geese is approximately 14 U/g*. The activity in the brains of 21 of 22 geese which were suspected of diazinon poisoning ranged from 1.5 to 6.8 U/g, and supporting the likelihood of their exposure to a ChE inhibitor (they were found dead on golf courses that had been sprayed with diazinon). The brain and plasma ChE activities in the American Kestrels were normal (compared to the controls). Control values for the other species were not available, but none appeared to be severely depressed.

* U/g - units of enzyme per gram of brain tissue

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5. DEVELOPMENT OF DATA BASES TO PROTECT THREATENED AND ENDANGERED SPECIES FROM RISK DUE TO PESTICIDE USE - (K.M. Lloyd, C. Downes and H. Dewar)

Introduction:

Protection of threatened and endangered species from pesticide use in Canada has not been adequately or systematically considered during the process of pesticide registration. Many of these species occur in areas where pesticides are used, and are potentially at risk due to either direct toxicity of the pesticide or its modifying effects on critical habitat. At present the magnitude of this problem is unknown.

Objectives:

The objectives of this study were:

1. to identify the threatened and endangered species whose habitats overlap with areas of pesticide use;
2. to identify and rank those pesticides and pesticide use patterns that may place a threatened and endangered species in jeopardy; and
3. to identify research and monitoring needs and regulatory and other strategies to reduce these risks.

Only the first of these objectives was addressed in this initial year of the study.

Methodology:

Data were collected on the distribution and biology for all species designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as threatened and endangered. Sources of information included the published literature as well as unpublished data from scientists studying each species. To develop and test methodology, a prototype based on 22 of these species was used. Distribution of each of the 22 species were mapped on the geographic information system SPANS and biological information for each species (i.e., specific habitat type, food, limiting factors, population size, etc.) was entered onto another computer data base.

As a surrogate for determining areas of use for specific pesticides, data on the distribution of various crops were used. Data for 86 crops, aggregated at the consolidated census subdivision level, were acquired from the 1986 Census of Agriculture by Statistics Canada. These data were also mapped using SPANS.

To determine those species whose distributions overlap specific crop distributions, and therefore, potentially 'at risk' from use of a pesticide on a specific crop, SPANS was used to overlay maps of species and crop distributions. This process acts only as an initial screen of the species, from which the data base containing biological information on each species is then used to further narrow the list of species to those most likely to be at risk.

Results and Discussion:

The prototype approach was useful in determining the adequacy of the data available and in identifying necessary refinements. In most circumstances, the level of aggregation of the crop information was at a scale that was too large to be of much use. Data aggregated at the finer level of enumeration area should be tried in the next phase of this project. Alternatively, at the level of aggregation used, data could be used to reduce the size of each census subdivision by limiting it to only those areas where agriculture occurs. For some species, particularly mammals and birds, very large ranges were identified. In these cases, the geographic information system may be of little use in screening out species potentially at risk. Detailed habitat information is likely to be more useful. Data acquired on species distributions were in various formats and considerable effort was required to convert the data into a format compatible with SPANS. An effort should be made to encourage biologists to collect data in a consistent format.

Provincial legislation concerning protection of threatened and endangered species was assembled to identify potential strategies to reduce risk. Current legislation in most provinces is inadequate to protect threatened and endangered species.

As new species are added and deleted each year by COSEWIC to the list of threatened and endangered species, annual updating of the data bases will be required. These data bases have several other potential uses (e.g., habitat impact assessment) and therefore could be used to identify risk to threatened and endangered species from sources other than pesticides.

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6. DEVELOPMENT OF DATA BASES ON WILDLIFE USE OF AGRICULTURAL HABITATS - (Dr. K. Freemark)

Introduction:

To identify and interpret the ecotoxicological significance of the effects of pesticides on Canadian wildlife and to provide advice and recommendations to prevent or mitigate these effects, data bases on wildlife use of habitats potentially exposed to agricultural pesticides are needed for Canada.

From 1986 to 1987, data bases were developed for evaluating the potential hazard to wildlife and their habitats from exposure to pesticides in agricultural areas. Wildlife use of habitats in agricultural areas in the Great Lakes-St. Lawrence region was examined as a prototype study for other regions of Canada. Special attention was given to croplands and adjacent habitats, and birds and their use patterns. Seventy habitat types characteristic of the agricultural areas were identified from census and published data. These include habitats which are regularly exposed to pesticides such as corn, soybeans, wheat, alfalfa, potato, apple, rights-of-way, as well as other less-intensively managed habitats such as pastures, hedgerows, woodlots, and wetlands. Hectarage per census district and for the region as a whole were abstracted for each crop type from the 1981 Census of Agriculture.

A data base on use of these habitats by wildlife in terms of time of year, activity (e.g., feeding, nesting, roosting), and intensity of use was compiled from the scientific literature. Although the database was largely drawn from studies in the United States, the information should be generally applicable in the Great Lakes-St. Lawrence region where similar crops and farming practices occur.

Objectives:

The objectives of this study were to further develop methods and collate data for evaluating the potential hazard to wildlife and their habitats from exposure to pesticides in the Great Lakes - St. Lawrence region of Canada.

Methodology:

Wildlife use data for each habitat type were collated and results were analyzed to produce foraging guild signatures for a selection of crops.

Results and Discussion:

In this project, the Great Lakes-St. Lawrence region is equivalent to the Mixed-Wood Plain (MWP) ecozone of the State of Environment Reports (Environment Canada, 1986, Statistics Canada, 1986). The MWP ecozone encompasses 19.5×10^6 ha. Pesticide use, habitat fragmentation, environmental contamination, and high-density road traffic are significant stresses experienced by wildlife in this ecozone.

Forty-one percent of the MWP ecozone is farmland. The remainder consists of forests, built-upon areas, lands used for nonrenewable resource extraction, wetlands, and fresh water. Farmland is comprised of rural nonfarm, croplands, managed pasture, native pasture, summer fallow, wetlands, brushy areas, and woodlands. The average farm is about 70 ha. In the MWP ecozone, 2.3×10^6 ha of farmland (29% of the total) were treated with herbicides, and 0.5×10^6 ha of farmland (6% of the total) with insecticides in 1980. This was an increase of 80% in area treated with herbicide and 63% increase in area treated with insecticide compared to 1970. Over 50% of the farmland in southern Ontario was treated with pesticides in 1980.

Pesticides may directly or indirectly affect the distribution or survival of wildlife and their habitats in agricultural landscapes in this region because of the quantity and extent of pesticides now being used, and the broad spectrum of their biological activity. Species-use profiles were generated for each habitat type to assess potential exposure of wildlife to pesticides. In croplands alone, 118 bird species and seven mammal species are potentially exposed. The distribution of bird species by foraging guild (e.g., insectivore, granivore, omnivore) varied among a selection of crops including alfalfa, apple, corn, potato, and soybean.

Wildlife use data can be coupled with crop area data to quantify the potential risk posed by the use of agricultural pesticides. The use of a geographical information system and the availability of land-use data bases for characterizing the extent and spatial configuration of habitats in a sample of regional landscapes was examined. The land-use data bases available are not detailed enough to be useful for analyzing habitat patterns for refining assessments of potential exposure of wildlife species and their habitats. Little information on wildlife use was available for crop types other than corn, soybean, wheat, oats, and tame hay. More basic research in agricultural habitats (particularly vegetable and fruit crops) must be done before any methods to evaluate the effects of pesticides on wildlife can be comprehensive. To address this knowledge gap, field work was initiated in 1987 for selected crops in Ontario.

Research efforts might also be directed towards determining species preference for no-till cropland versus conventionally-tilled cropland since conservation tillage is expected to increase in Canada. The exposure of wildlife to pesticides routinely used in these fields may pose a serious problem since no-tillage fields have higher bird densities and are used by a greater variety of birds during the breeding season than fields with less crop residue. How the potential exposure of wildlife to agricultural pesticides is affected by landscape patterns such as availability of cultivated versus uncultivated habitat, distance from croplands to uncultivated areas, availability of cover for nesting, or availability of food resources such as invertebrates, waste grain, weed seeds, and small mammals should also be addressed. The use of pesticides in study areas should also be investigated to assess the ecological situation prior to pesticide use to quantify ecological side-effects of these chemicals which may already have occurred.

The results were presented at the annual meeting of the Society of Environmental Toxicology and Chemistry (SETAC). The response at SETAC indicated that the results would be widely used if available. Further development of the database and dissemination of the information is planned for 1988/1989.

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7. DEVELOPMENT OF GUIDELINES FOR TESTING PESTICIDE TOXICITY TO NONTARGET PLANTS - (Dr. K. Freemark and P. MacQuarrie)

Introduction:

Environment Canada is concerned about the potential hazards posed to nontarget organisms and their habitats from exposure to pesticides during application, or from accidental overspray, spray drift, runoff, or leaching.

Herbicides, for example, have been shown to affect the success of birds through critical alterations in habitat. A well-documented example of the effect of herbicides on an avian species is the recorded reduction in Grey Partridge (*Perdix perdix*) populations in English farmlands (G.R. Potts, Adv. Ecol. Res., 8: 2-79 (1980)). Experiments demonstrated that the use of herbicides in the removal of broadleaf weeds in cereal crops resulted in the reduction of preferred insect food resources sufficient to account for the reported reductions in chick survival. Large-scale, controlled and replicated experiments indicated that Partridge brood size, and hence chick survival, was significantly higher where edges of cereal fields were left unsprayed (M.W.R. Rands, J. Appl. Ecol., 22:49-54 (1985)).

Although there is insufficient data to directly correlate pesticide use in Canada with the declining success of prairie waterfowl, there is evidence to suggest that the extensive application of herbicides in the pothole region may adversely alter food, nesting, and protective cover in uplands, sloughs, and slough margins for some resident duck species (Sheehan et al., CWS Techn. Rep. 19 (1987)).

Protection of plants other than agronomic species such as crops, ornamentals, etc., is not adequately and systematically considered during the process of pesticide registration in Canada. A project was initiated to address this need and to provide a basis for development of guidelines for testing pesticide toxicity to nontarget plants.

Objectives:

The objective of this study was to review and evaluate international requirements and the "state-of-the-art" for testing pesticide toxicity to nontarget plants, and to establish an interdepartmental working committee for discussing issues related to the development of guidelines for Canada.

Methodology:

A contract was let to the Saskatchewan Research Council (SRC) to: review existing requirements for testing pesticide toxicity to nontarget plants for other international agencies; evaluate problems with regulatory guidelines and tests used; identify knowledge gaps regarding phytotoxicity testing; and provide conclusions and recommendations for developing guidelines for Canada. A mechanism for involving other government departments in the development of nontarget plant testing guidelines was established.

Results and Discussion:

The final report submitted by SRC was based on a review of the scientific literature, and consultations with phytotoxicity experts in Canada and abroad, conducted in part by a questionnaire.

Guidelines and tests for U.S. EPA, OECD, EEC, UK, and Australia, and alternative test protocols were reviewed and evaluated. The available algal growth tests were considered satisfactory provided test duration did not exceed 72 hours and initial cell numbers were low. Testing a battery of algal species was recommended in place of the current practice of testing a single species. The algal microplate technique was a very promising method because of its speed, efficiency, and low cost (although it requires further testing and validation). Test protocols for *Lemna* were generally satisfactory but require some refinement. Terrestrial plant germination, growth, and vigour tests, although required by the U.S. EPA and OECD, have not been widely used and require more refinement, especially regarding endpoints. Terrestrial plant tests should include more ecologically important species. Field testing for pesticide toxicity to nontarget plants has been included in the U.S. EPA guidelines, but has not been commonly used, and still requires development or rigorous sampling designs and clear unambiguous endpoints.

Information gaps were also identified and methods available to fill these gaps were reviewed. No standard protocols exist for testing rooted aquatic macrophytes. This field merits further research and development. Pollen germination tests are widely described in the scientific literature, and development of a standard protocol for possible inclusion in regulatory guidelines should be considered. Standardized aquatic microcosm designs are available, show good agreement with field results, and should be considered for inclusion in test guidelines. Terrestrial microcosms need more research and standardization. Mesocosm tests can be useful for fine-tuning laboratory and field tests.

An Interdepartmental Working Committee, under the chairmanship of Environment Canada and involving Fisheries and Oceans Canada, Agriculture Canada, and the Canadian Forestry Service, was established to provide a forum for reviewing the interim and final reports submitted by SRC, and for discussing other issues related to the development of guidelines for testing pesticide toxicity to nontarget plants for Canada.

This project has provided an important background document and consultative mechanism for identifying regulatory needs and potential areas of future research, and for discussing and drafting guidelines for testing pesticide toxicity to nontarget plants for Canada.

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8. EVALUATION OF THE USEFULNESS OF AVIAN REPRODUCTION STUDIES AS CURRENTLY DESIGNED - (D.C. Boersma, P. Mineau, and G.A. Fox)

Introduction:

Before we can write comprehensive Canadian guidelines for environmental toxicology testing and evaluation, we need to assess the usefulness of the guideline components currently in use under the U.S. registration system. (Most data packages generated worldwide currently follow U.S. guidelines). The avian reproduction study is the most expensive laboratory test carried out on a routine basis on wildlife species. This test was initially designed to detect compounds which have a tendency to bioaccumulate and cause problems such as eggshell thinning. Its usefulness in detecting problems caused by short-lived cholinesterase-inhibiting insecticides, herbicides, or fungicides has never been systematically investigated.

Objectives:

This is the first year of a project scheduled to run over a three-year period. The objectives were to evaluate as many avian reproduction studies as possible to determine:

1. how often this type of study detects a problem of reproductive toxicity;
2. if the same answers can be obtained from other tests (e.g., mammalian reproductive tests); and
3. if the current test guidelines should be modified to make the test more relevant or more useful.

Results and Discussion:

A total of 121 studies on 62 different pesticides have been evaluated to date. In many cases, raw data have been computerized and statistical analyses performed de novo.

One of the major problems to overcome has been the lack of comparability between studies as a result of the varied analyses of the results. All studies are being re-analyzed in the same way to ensure uniformity. Several biostatisticians have been consulted and will be cooperating on the project.

It is already apparent that a large proportion of studies were conducted at dose levels below expected environmental concentrations as estimated from recommended application rates and reported residue concentrations. The validity of these studies is therefore in question.

A report is scheduled for the end of the 1988-89 fiscal year.

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APPENDIX

ENVIRONMENT CANADA'S INPUT TO DISCUSSION DOCUMENTS

Environment Canada's Input into Discussion Documents

Agriculture Canada has issued three series of documents to provide information on new developments on pesticide regulatory issues: CAPCO Notes, New Product Notes, and Discussion Documents. CAPCO Notes and New Product Notes provide an informal update of the regulatory status of products or a brief summary on the uses of a new product. Discussion Documents provide a summary of the scientific data on a product, outline the rationale for any regulatory action, discuss the options available, and solicit comments and feedback on difficult regulatory decisions. These documents also describe special situations that can arise as a result of a need to register a new pesticide active ingredient or a new use with data gaps or special concerns.

Input into Discussion Documents is provided by Agriculture Canada and its core advisors: Health and Welfare Canada, Fisheries and Oceans Canada, and Environment Canada. To date, Discussion Documents on five active ingredients: oxyfluorfen, pentachlorophenol, triadimefon, metsulfuron-methyl, and propiconazole, have been publicly released by Agriculture Canada. The following is the input by Environment Canada (Environmental Protection and the Canadian Wildlife Service) into each of these documents.

OXYFLUORFEN

Summary - More data are needed to determine the environmental acceptability of oxyfluorfen. The high aquatic toxicity and persistence in sediments are of special concern. There are no data on the environmental fate of oxyfluorfen in muck soils on which dry bulb onions are grown in Canada. A mitigating factor is the small size of the area that is planted to dry bulb onions in any year.

Environmental Chemistry and Fate - The solubility of oxyfluorfen in water is very low, and this chemical is readily adsorbed to a variety of soils, particularly those with high organic matter content. Little desorption into water occurred in test soils, indicating that leaching of oxyfluorfen from treated soil would be minimal. The vapour pressure of oxyfluorfen is low; nonetheless, measurable concentrations of the chemical were found in the air above a treated field (silt-loam soil, 2.5% organic matter) and this may be a significant route of dissipation. The air/water distribution ratio or Henry's law constant is relatively high (close to that of triallate) which supports the potential for volatilization. The very strong adsorption of oxyfluorfen on soil organic matter, however, makes volatilisation an unlikely route of dissipation from muck soils. The fate of the vapourized chemical is unknown.

Field studies on the decline of the chemical's concentration in soil residue (not in muck soils) have shown varied half-lives (50% decline times) ranging from 9 days to 95 days.

In one U.S. field study, significant contamination of hydrosoil was found in a farm pond, on a site subject to erosion by runoff, within an area of oxyfluorfen use. This type of erosion is not likely to be characteristic of muck areas on which dry onion bulbs are grown in Canada. In such areas, the likelihood of movement of oxyfluorfen adsorbed on suspended organic matter in drainage water will depend on the hydraulic regime imposed and the timing of tillage in relation to application of goal.

Environmental Toxicology

Wild Birds: The acute toxicity of oxyfluorfen to 16-week old Bobwhite Quail is approximately 5000 mg/kg with mortality occurring between 4 and 14 days after dosing. The 5-day dietary toxicity (followed by three days of observation on clean food) was greater than 4000 ppm for 5-to 7-day old mallard ducks and 390 ± 22.7 ppm for 5- to 7-day old Bobwhite. Feeding depression was noted at 1000 ppm for mallards and 100 ppm for bobwhites. Symptoms of toxicity were observed at the lowest diet concentrations tested, namely 2000 ppm in the Mallard and 100 ppm in the Bobwhite. The lowest diet concentration which caused mortality in the Bobwhite was estimated to be between 100 and 300 ppm, whereas no mortality was observed in the Mallard at 4000 ppm. In reproductive studies consisting of 11 to 12 weeks of dietary exposure pre-laying followed by 10 weeks of egg laying while still on the contaminated diet, no effects were seen up to 100 ppm in either the Mallard or Bobwhite. Information on diet stability was not included and has been requested from the manufacturer so that the studies can be properly evaluated.

If there is contamination of wetland, chronic dietary exposure is likely to result from subsequent uptake of plant and animal foods. Only limited exposure is expected from the use of oxyfluorfen on onions. Based on these considerations, oxyfluorfen is not expected to present an acute hazard to avian species. Although the reproduction studies submitted could not be evaluated fully a chronic hazard is not likely.

Wild Mammals: No wild mammals were tested. Based on the low acute toxicity of oxyfluorfen to the rat and dog (range: 3200 mg/kg to >7100 mg/kg) acute toxicity is not expected in wild mammals. The formulated product was found to be somewhat more toxic than the technical, the rat LD_{50} being between 500 and 5000 mg/kg.

Amphibians and Reptiles: No data are available for the evaluation of risk to amphibians or reptiles. Exposure to amphibians is likely if there is contamination of wetlands.

Aquatic Invertebrates: Oxyfluorfen is very toxic to some aquatic invertebrates such as crustacea and molluscs. Endpoints of toxicity studies submitted in support of registration are:

Species	Endpoint		Result (in active ingredient)
Daphnia magna	48-h	LC_{50}	1.5 mg/L
Grass shrimp *(P. pugio)*	96-h	LC_{50}	0.032 mg/L
Freshwater clam *(E. complanata)*	96-h	LC_{50}	9.6 mg/L
Eastern Oyster *(C. virginica)*	48-h	EC_{50}	>0.032 mg/L

No data were submitted on the toxicity of formulated material; therefore, these values must be considered as underestimates of the toxic potential of formulated oxyfluorfen. The U.S. EPA has concluded that several species of endangered molluscs could be at risk from the use of oxyfluorfen in the United States.

Exposure to oxyfluorfen is expected to occur if there is sediment transport in runoff from treated fields. Residues are expected to be persistent and to accumulate, to some degree, in the biota.

Terrestrial Invertebrates: No data were provided on the toxicity of oxyfluorfen to earthworms or terrestrial insects. Tests on a number of soil microorganisms showed no effect at expected field concentrations.

Wildlife Habitat Considerations: The removal of animal food organisms from wetlands associated with areas of use is one of the potential impacts on wildlife habitat. Another is the phytotoxicity of oxyfluorfen residues to aquatic plants. Field soil residue levels below the detection limit (10 ppb) were found to be still herbicidally active. There is a possibility that the contamination of receiving wetlands by sediment in runoff will affect important food plants such as aquatic macrophytes. Oxyfluorfen is known to be phytotoxic to green alga *Scenedesmus acutus* but the full spectrum of its activity should be investigated to determine the probable effects.

PENTACHLOROPHENOL

Environmental Aspects - Although this discussion document primarily addresses pentachlorophenol, it also directly relates to the closely associated chlorophenols and the impurities and microcontaminants present in most pentachlorophenol formulations.

The 1981 Environment Canada publication Chlorophenols and Their Impurities in the Canadian Environment and the 1984 supplement to that publication provide information on the environmental problems associated with pentachlorophenol in Canada. These publications are also an inventory of evidence that chlorophenols persist in the environment, bioaccumulate, and are highly toxic to aquatic organisms.

Residues of chlorophenols have been detected in a wide range of environmental samples including surface and groundwaters, snowpack, landfill leachate, industrial and sewage effluents, sediments, and in aquatic and terrestrial organisms. Although most of the residues are associated with point-source releases, the inevitable conclusion was that chlorophenols have become ubiquitous in the Canadian environment.

The widespread use of pentachlorophenol and tetrachlorophenol for industrial and domestic purposes has also contributed to the environmental distribution of their impurities and micro-contaminants, such as polychlorinated phenoxyphenols and polychlorinated dibenzofurans.

Sources to the Environment - Domestic uses of pentachlorophenol can be considered non-essential because there are adequate replacement products for this limited market. Contribution to the total loading of pentachlorophenol into the environment from domestic use, however, is important in that pentachlorophenol use is in a high exposure area.

To date, pentachlorophenol and tetrachlorophenol have been the primary chemicals used to protect wood from fungi associated with decay and staining of wood, both prior-to and in-service. Wood processing plants have been identified as the major point sources for release of chlorophenols to the environment. These releases have probably occurred ever since the plants were commissioned.

The losses, mostly unintentional, have been through effluents, emissions, and fugitive releases from the wood treatment plants, sawmills and planer mills with wood protection facilities.

Although all the data have not yet been compiled and evaluated, monitoring studies at chlorophenol use sites in British Columbia have demonstrated that major losses of chlorophenols to the environment probably occur during and following precipitation events. These events result in wash-off and leaching of chlorophenols from recently treated wood stored unprotected in the open environment.

Monitoring for chlorophenols and their contaminants at wood preservation plant sites has demonstrated that these plants can be major sources of chlorophenol pollution.

Environmental Toxicology - Pentachlorophenols and tetrachlorophenols are of toxicological significance to many organisms, particularly those in the aquatic environment. Most biota are equally sensitive to pentachlorophenol (PCP). Based on laboratory experiments, the "No Observed Effect Level" for pentachlorophenol in estuarine benthic communities was approximately 14 µg PCP/L. Although the acute toxicity of chlorophenols to aquatic biota is well known, the effects of low-level chronic exposure to chlorophenols are not. As well, the toxicological role of the microcontaminants in chlorophenols have yet to be fully documented and assessed.

Environmental Chemistry, Fate, and Mobility - Of the various mechanisms affecting environmental transport of chlorophenols, adsorption to sediments resultant movement in water predominate. The higher chlorinated phenols are only slightly soluble in water, but the sodium salts of these compounds used for wood protection are highly soluble in water.

In a natural aquatic environment bioaccumulation of chlorophenols in biota can be moderate to high, even though depuration may proceed at a moderate rate, as influenced by pH and other chemical and physical factors.

Significant pathways for the removal of tetrachlorophenol and pentachlorophenol from an aquatic environment are losses through photolytic activity in the surface layer and through biodegradation. Biological degradation in an aquatic environment is enhanced by the presence of acclimated bacteria. Under anaerobic conditions, as in anaerobic sediments, biodegradation is greatly retarded.

Transport of chlorophenols in the environment may mean the transport of associated impurities. Depending on the type of formulation and environmental conditions; however, differential retention takes place when the chlorophenols and their contaminants move through sediment and soil. The most direct evidence of this has been obtained near wood treatment facilities which are point sources for chlorophenols. The significance and implications of these findings are additional reasons for concerns which must be addressed.

Protection of the Environment - In 1981 Agriculture Canada implemented a series of regulatory measures to help address the chlorophenol environmental concerns identified and documented by Environment Canada. The remaining uses for chlorophenols are primarily those encompassed in domestic class products and in industrial wood treatment products. Environmental concerns rest on the industrial uses.

The major problems that arise from use of chlorophenols at wood treatment facilities are:

1). loss of chlorophenols and their microcontaminants into the aquatic environment;
2). disposal of waste chlorophenol formulations; and
3). disposal of chlorophenol-contaminated wood wastes and sludges.

On the positive side, to reduce the loading of microcontaminants associated with pentachlorophenol into the environment, current formulations of pentachlorophenol, approved for use in Canada by Agriculture Canada, have a much lower content of hexa-dioxins than those used previously. Other impurities and microcontaminants, such as the polychlorinated phenoxyphenols, lower chlorinated dibenzo-p-dioxins, and polychlorinated dibenzofurans, however, are not usually assayed for and their levels in the current chlorophenol formulations are for the most part unknown. From an environmental viewpoint this concern must be addressed and monitoring for chlorophenols presence in environmental samples must also be carried out if chlorophenols are to continue to be in use.

Since the main uses of chlorophenols are for wood treatment in an industrial setting, protection of the environment from point source contamination by chlorophenols rests, for the most part, with adequate protective measures at wood treatment sites. To assist the British Columbia sawmill industry in this regard, a document commonly known as a "Code of Good Practice", containing recommendations for design and operation of chlorophenate wood protection facilities, was developed jointly by the British Columbia Ministry of the Environment and Parks, and the Pacific Regional Office of the federal Department of the Environment. This Code is now being further developed and implemented nationally as are companion technical recommendation documents for wood preservation facilities.

It may be necessary to introduce other regulatory options to control the release of the chlorophenols if additional regulations under the *Pest Control Products Act*, and the implementation of control measures (as set out in the technical recommendations manuals for design and operation of industrial wood treatment plants) fail to eliminate further environmental contamination. Chlorophenols may, over a period of time, be phased out as a result of domestic pressures and international marketplace requirements for Canadian wood products and most replacement products, to be effective, will be toxic to fungi and other microorganisms and, therefore, are likely to be toxic to aquatic life. The basic characteristics of the replacement products, however, are probably more environmentally acceptable than the chlorophenols.

There is, and will continue to be, a need for appropriate safety measures, both regulatory and operational, for the wood treatment facilities in order to protect the environment from chemical abuse.

Reference

Kitunen, V.H., R.J. Valo, and M.S. Salkinoja-Salonen, "Contamination of Soil Around Wood-preserving Facilities for Polychlorinated Aromatic Compounds," Environ. Sc. Technol., 21(1): 96-101 (1987).

TRIADIMEFON

Summary of Environmental Aspects - Triadimefon (Bayleton™) persists to the extent that it has a reported half-life of a few weeks to a few months in soil. Its primary metabolite is triadimenol (the active ingredient of Baytan™) which is more persistent. More data are needed to define the persistence and the potential mobility. Additional information is also needed concerning possible effects on birds, demonstrated toxicity in aquatic organisms, and effects on wildlife habitat (especially in wetlands).

Environmental Chemistry and Fate - The solubility of triadimefon in water at 20°C is 60 ppm, and its octanol-water partitioning coefficient is 972. Triadimefon is readily adsorbed to all soil types including sand, loam, and silty clay. Neither triadimefon nor its primary metabolite, triadimenol, is very readily leached from soils. The vapour pressure of triadimefon is low and volatilization will also be low.

Triadimefon is somewhat persistent in soil to the extent that it has a reported half-life of a few weeks to a few months. The primary metabolite, triadimenol (which is also a fungicide in its own right) is more persistent, having a half-life in soil of at least some months. Further field soil dissipation studies under Canadian conditions are warranted to define the accumulation and depth of penetration of triadimenol in the soil profile with repeated use of Bayleton™.

Triadimefon or its transformation product, triadimenol, is unlikely to enter sensitive aquatic systems through leaching. Although they could enter as a result of erosion, the most likely route of contamination is through spray drift of Bayleton™. Triadimenol has been shown to be more persistent than triadimefon in sediment as well as in soil.

Environmental Toxicology

a) Wild Birds. The toxicity of triadimefon to wild birds is low. No mortalities of adult mallard ducks were observed when dosed with 4000 mg of the technical material/kg body weight. The eight-day dietary LC_{50} is between 4640 and 10 000 mg/kg diet for bobwhite quail. No mortalities of mallard ducks were observed at 10 000 mg/kg diet.

Although the manufacturer has indicated that studies on the effects of triadimefon on reproduction of bobwhite quail and mallard ducks have been done, these studies have not been evaluated. Triadimenol a major degradation product of triadimefon, was evaluated for reproductive effects on bobwhite quail. The compound was fed for 10 weeks prior to laying and throughout a 13-week laying period at concentrations of 0, 20, 100 and 500 mg/kg diet. No effects were observed on adult survival, body weight, feed consumption, egg cracking, fertility, viability, hatching, chick survival, and chick weight at 0 and 14 days. A 15% reduction in egg production at the highest dose level indicated maternal toxicity.

Exposure to triadimefon is unlikely to be acutely toxic to wild birds. Effects due to chronic exposure through ingestion of contaminated grain cannot be fully evaluated as the studies on the effects of the active ingredient on avian reproduction have not been received.

b) Wild Mammals. Triadimefon technical was not highly toxic to laboratory rats, mice, rabbits, or dogs. Acute oral LD_{50} values ranged from 363 to 568 mg/kg for rats, 989 to 1071 mg/kg for mice, 500 mg/kg for rabbits, and 500 mg/kg for dogs. No wild mammals were tested.

On the basis of estimates of exposure following recommended application rates on wheat, triadimefon is not expected to pose an acute toxic hazard to wild animals.

c) Amphibians and Reptiles. No data are available for evaluation of risk to amphibians and reptiles.

d) Aquatic Organisms. The acute toxicities of the technical and formulated product (50 WP) to aquatic invertebrate species are moderate. The 48-h LC_{50} (static water test) to *Daphnia* is 1.6 to 11.3 mg active ingredient/L for the technical and 16 mg active ingredient/L for the formulated product. The no-effect concentration of the formulated product was 5.6 mg/L.

Studies on the acute toxicity of triadimefon suggest that crayfish are less sensitive to the compound than *Daphnia*, having a 96-h LC_{50} of 104 mg/L. The reliability of these results is questionable because the nominal concentrations were not confirmed analytically and are above the water solubility of the compound.

If spray drift at rates recommended for use of Bayleton™ on wheat should deposit on water, chronic exposure to triadimefon and triadimenol could affect aquatic organisms, especially those living in or on the sediment.

e) Terrestrial Invertebrates. No effect on numbers of earthworms was observed after 10 days in soil containing triadimefon at 50 mg/kg soil.

Studies on selected soil microorganisms showed varied species sensitivity. Growth of one of the five species of bacteria and actinomycetes tested was inhibited at 2 ppm triadimefon in soil, and growth of one of the four species of fungi was inhibited at 10 ppm.

No effects on soil nitrification or denitrification have been observed.

At application rates recommended for use, triadimefon concentrations of at least 1 ppm in soil can be expected to occur. Some populations of soil microorganisms could potentially be affected.

f) Wildlife Habitat Considerations. There is evidence for effects on plant growth at low concentrations. Growth of soybean plants was significantly reduced (60% decrease in shoot length, 21% decrease in plant fresh weight) relative to controls following continuous irrigation for four weeks with a 0.5 mg/L solution of triadimefon. No data are available on the phytotoxicity of triadimefon to aquatic plants. Triadimefon could reach aquatic systems such as prairie sloughs; therefore, the impact on aquatic plants and subsequently on wildlife wetland habitat must to be defined.

METSULFURON-METHYL

Summary - The prominent modes of degradation of metsulfuron-methyl in soil, water, and sediment are by microbial action under aerobic and anaerobic conditions and by chemical hydrolysis (chemical hydrolysis being significant only under acidic conditions). Photodegradation is insignificant. Residues degrade faster in warm, moist soils of low pH. In prairie soils herbicidally-active residues persist for at least two growing seasons. High water solubility, poor soil adsorption and results of laboratory leaching experiments suggest metsulfuron-methyl has a significant potential for movement through leaching and run-off. Field studies with technical material in the prairies have provided variable results but, in general, indicate that leaching was limited and was related to amount of rainfall and soil type. Field studies with formulated material to assess movement through leaching and runoff are pending.

The requested use of metsulfuron-methyl is not expected to pose a hazard to wildlife from acute or dietary exposure or from food removal caused by low acute toxicity to invertebrates. The effects on wildlife habitat and associated food resources, however, cannot be evaluated because minimal-effect-levels for nontarget plants have not been determined. The data submitted indicate that metsulfuron-methyl is likely to be toxic to aquatic plants at initial concentrations expected in prairie sloughs in the intended area of use. Algal toxicity tests and toxicity tests with plant species commonly associated with prairie sloughs are pending. These tests will: 1). evaluate potential effects of metsulfuron-methyl on wildlife habitat and associated food resources in the intended area of use; and 2). determine if the current detection limits for metsulfuron-methyl in water and soil are adequate. In the interim, a 15-m buffer zone is suggested around sloughs and other wetlands to minimize possible off-site movement of metsulfuron-methyl and exposure of nontarget plants.

Environmental Chemistry and Fate - Metsulfuron-methyl is a weak acid (pKa = 3.5), the non-ionic form predominating at low pH. It is highly water soluble (109 mg/L in distilled water at 25°C), particularly under buffered conditions and higher pH (270 mg/L at pH 5, 9500 mg/L at pH 7). Its higher water solubility is also reflected in its low octanol-water partition coefficient (Kow = 0.018). Metsulfuron-methyl is moderately volatile with a vapour pressure of 7.7×10^{-6} kPa at 25°C.

The prominent modes of metsulfuron-methyl degradation in soil, water, and sediment are by microbial action under aerobic and anaerobic conditions. Chemical hydrolysis is also significant under acidic conditions. Photodegradation in soil or water is insignificant. In soil, the parent compound is degraded to saccharin and carbon dioxide by way of intermediate transformation products.

Metsulfuron-methyl is very persistent in cool, dry, alkaline soils. In a laboratory study with Canadian prairie soils, the half-life was 70 days in clay loam (pH 5.2), 102 days in sandy loam (pH 6.8), and 178 days in clay soil (pH 7.5). Field studies using radio-labelled metsulfuron-methyl in silt loam, silty clay loam and sandy loam soils (pH 6.1 to 8.2) in the northern U.S. and Canada (Alberta, Saskatchewan, and Manitoba) indicated an average 50% decline time (DT_{50}) of 2.5 months (range of one to seven months). The parent compound, however, persisted in the soils for at least two growing seasons. No data were available on the fate of transformation products. Differences in persistence between laboratory and field studies were a result of some combination of factors related to soil pH, moisture, and temperature.

In prairie soils, herbicidally-active residues persist for at least two growing seasons. A recropping interval of 22 months or more depending on the results of a preliminary field bioassay, may be necessary for crop rotation. Some tolerant crops may be grown after 10 months. Regular annual use of the product may lead to accumulation or buildup of residues although no data were available.

A laboratory anaerobic water/sediment study conducted at 25°C indicated that the approximate DT_{50} in natural water ranged from five weeks at pH 5.8 to 25 to 30 weeks at pH 6.9. Because the water in prairie sloughs is mainly alkaline (pH up to 9.7) and well buffered, metsulfuron-methyl is expected to persist in the water column for more than 30 weeks and therefore potentially accumulate from regular annual use. Studies on persistence of metsulfuron-methyl in water and sediment have been suggested to address this concern.

Studies with acid soils (pH 5.6 to 6.5) indicate that metsulfuron-methyl adsorbs poorly in soils. Soil column experiments with freshly-treated acid soils (pH 5.6 to 6.7) showed that 85% to 100% of the applied radioactivity leached through the columns. A soil thin layer chromatography (TLC) study also indicated that metsulfuron-methyl was mobile in sandy loam and silt loam soils. In soils with a higher pH, the mobility is expected to increase because of increased solubility, increased ionization of the chemical and decreased adsorption. Results from field studies in the prairies with radio-labelled technical material were variable, but in general indicate that leaching was limited and was related to amount of rainfall and soil type. There was very little leaching (1%) below 22 cm in the dark brown soil at Swift Current (silt loam, pH 6.1) and Saskatoon (silty clay loam, pH 6.2). In the black soil at Stettler, Alberta (sandy loam, pH 6.9), however, 12% of the applied activity had leached down to 22 to 35 cm soil depth after one month. There was no indication that leaching had stopped at 35 cm as soil from a greater depth had not been sampled. Field studies with formulated material to assess leaching in black- and grey-wooded soils are pending.

Metsulfuron-methyl, because of its high water solubility and poor soil adsorption, has a potential for movement in runoff water if there is rainfall soon after application. This could result in contamination of adjacent wetlands and subsequent damage to nontarget plants. Field runoff studies based on the use of indicator plants are pending. In the interim, a 15-m buffer zone is suggested around sloughs and other wetlands to minimize contamination of adjacent nontarget habitats.

Environmental Toxicology

Wild Birds. Wild birds may be exposed to metsulfuron-methyl by direct overspray, spray drift, or by consumption of vegetation or prey sprayed with this herbicide. Exposure through these routes is not expected to result in adverse toxicological effects because of low application rates and residues, and the extremely low acute oral and dietary toxicity of the technical and formulated product to bird species tested. Technical metsulfuron-methyl is practically non-toxic to six-month old mallards (LD_{50} >2510 mg/kg). Technical metsulfuron-methyl was not toxic to 14-day-old Mallards or Bobwhite quail when administered in the diet for 5 days (both LC_{50}'s >5620 ppm).

Wild Mammals. Wild mammals may be exposed to metsulfuron-methyl by direct overspray, spray drift, or by consumption of vegetation or prey sprayed with this herbicide. Exposure through these routes is not expected to result in adverse effects because of: 1). low application rates and residues; and 2). the extremely low toxicity of the technical and formulated product to laboratory mammals exposed by oral, dermal, or respiratory routes.

No mortalities were observed in rats administered single oral doses of 5000 mg/kg of the active as technical grade or formulated product. Acute oral tests on single rats indicated 25 000 mg/kg of technical material was not lethal. The approximate lethal oral dose in dogs was greater than 2500 mg/kg. Orally administered metsulfuron-methyl is very rapidly cleared by rats and ruminants, predominantly in the urine.

Metsulfuron-methyl administered orally to rats as ten repeated doses up to 3400 mg/kg over two weeks showed only slight weight losses. Mice exposed to dietary doses as high as 5000 ppm for 90 days showed only decreases in body weight gain associated with decreased food consumption. Dietary concentrations as high as 5000 ppm were not toxic to rats fed continuously for two years. Dogs consuming a diet containing 5000 ppm for one year were also not affected.

In rabbits, the acute lethal dermal dose was greater than 2000 mg/kg of the active as technical grade or formulated product. Rabbits exposed dermally up to 2000 mg/kg of the technical material for 21 days showed no compound-related effects. Rats inhaling doses up to 5.3 mg/L of technical material were not adversely affected.

Metsulfuron-methyl had no embryopathic or teratogenic potential when orally administered to rats at concentrations as high as 1000 mg/kg or to rabbits at 700 mg/kg.

Amphibians and Reptiles. No data are available; however, this herbicide is not expected to be hazardous to amphibians and reptiles given the plant-specific mode of action of metsulfuron-methyl and its low acute toxicity to aquatic invertebrates and fish (LC_{50}'s >150 mg/L).

Terrestrial Invertebrates. Metsulfuron-methyl is nontoxic to honey bees. *Apis mellifera* (contact LD_{50} >25 µg/bee), and earthworms (LC_{50} >1000 mg/kg). The requested use of metsulfuron-methyl is not expected to pose a hazard to terrestrial invertebrates from acute toxicity. However, terrestrial invertebrates may be at risk from plant removal in nontarget habitats as a result of contamination by metsulfuron-methyl.

Aquatic Invertebrates. Metsulfuron-methyl was not acutely toxic to *Daphnia magna* at concentrations as high as 150 mg/L (v/v). Aquatic invertebrates should not be at risk from acute toxicity as a result of contamination by metsulfuron-methyl. However, aquatic invertebrates may be at risk from the loss of plants commonly associated with sloughs.

Soil Microbial Systems. Little information was available on the effect of metsulfuron-methyl on soil ^{14}C microorganisms. A laboratory study on ^{14}C-cellulose digestion showed that there was limited effect on anaerobic microorganisms in sediment.

Wildlife Habitat Considerations. The use of metsulfuron-methyl is not expected to pose a hazard to wildlife from food removal associated with acute toxicity to terrestrial or aquatic invertebrates (although data were limited). The impact on wildlife habitat and associated food resources from the use of metsulfuron-methyl cannot be evaluated because the minimal-effect-level for nontarget plants has not been determined.

Metsulfuron-methyl is absorbed by foliage and roots and is translocated. Metsulfuron-methyl inhibits cell division in the shoots or roots by blocking synthesis of the amino acids valine and isoleucine. Sensitivity of plant species is related to the rate of metabolic inactivation of metsulfuron-methyl.

No data were available for algae or other nontarget plants to determine minimal-effect-levels of metsulfuron-methyl. Some data on the effects of this herbicide on aquatic macrophytes were available for efficacy studies in the laboratory and in rice paddies in southeast Asia. Although these studies were not designed to determine minimal-effect-concentrations, they do indicate that this herbicide is phytotoxic to aquatic plants at very low concentrations in water.

The most sensitive aquatic plants reported were the submerged species, *Potamogeton nodosus* and *P. pectinatus*. Growth in shoot length was inhibited by 77% to 90% relative to the control four weeks after treatment at a nominal rate of 1 µg/L prior to plant emergence from the soil. As 1 µg/L was the lowest rate tested, the minimum-effective-concentration for growth inhibition is unknown. However, a concentration of 0.05 µg/L or less is not unreasonable to assume based on the dose-growth response of submersed aquatic plants to other sulfonyl ureas or other herbicides.

Efficacy studies in rice paddies in southeast Asia indicated that metsulfuron-methyl provided 90% to 100% growth inhibition of submersed, floating and emergent broadleaf plants at treatment rates of 2 to 3 g active ingredient/ha. Little or no control of emergent grasses was reported at rates as high as 8 g active ingredient/ha.

Since the minimal-effect-level for nontarget plants has not been determined, the impact on wildlife habitat and associated food resources from the use of metsulfuron-methyl cannot be evaluated. The data submitted, however, indicate that metsulfuron-methyl is likely to be toxic to aquatic macrophytes at initial concentrations expected in slough water from runoff. Exposure of floating, emergent, and slough-margin vegetation to overspraying from ground application and spray drift into nontarget habitats adjacent to use areas is also potentially hazardous. In addition, as metsulfuron-methyl has a high degree of residual phytotoxicity in soil and in water/sediment, repeated use of metsulfuron-methyl could pose an additional hazard to plants in nontarget habitats from residue accumulation in soil or water.

Sloughs in the prairie pothole region of Canada support a substantial portion of North American waterfowl populations during the breeding season. Reproductive and recruitment success depends on continued access to a variety of sloughs (e.g., temporary, semi-permanent, permanent) which provide a balance of protective cover and appropriate nesting vegetation as well as plant and aquatic invertebrate food resources for laying hens and young ducklings from mid-April to late September.

Algal toxicity tests and toxicity tests with plant species commonly associated with prairie sloughs are pending. These tests will evaluate potential effects of metsulfuron-methyl on wildlife habitat and associated food resources in the intended area of use. They will also determine if the current detection limits for metsulfuron-methyl of 0.1 µg/L in water and 0.2 µg/L in soil are adequate.

PROPICONAZOLE

Summary - Propiconazole undergoes fairly slow microbial degradation in aerobic conditions in soil, sediment, and water. Under anaerobic conditions propiconazole will be persistent. A major degradation product of propiconazole also undergoes microbial degradation only slowly. Photochemical transformation of propiconazole occurs in water but the rate of this process in natural waters is not known.

When applied at label rates, propiconazole is not expected to pose a direct hazard to wild birds or mammals, or terrestrial and aquatic invertebrates. Of concern is the high toxicity of propiconazole to some algal species. Because wetland areas are important habitats for wildlife, the integrity of wetland areas must be maintained. A 15-m buffer zone should be used around all wetland areas so that propiconazole will not enter these sensitive ecosystems.

Environmental Chemistry and Fate - The solubility of propiconazole in water at 20°C is 110 mg/L, the octanol-water partitioning coefficient is 4500, and the vapour pressure is 1.3×10^{-4} Pa. The air-water distribution ratio or Henry's Law constant is very low; therefore, volatilization of propiconazole from wet substrates will be low. Hydrolysis of propiconazole in water does not occur under environmentally-relevant conditions.

Propiconazole is strongly adsorbed to most soils. In laboratory leaching studies on four soil types (sandy soil, sand, silty loam, and sandy loam) propiconazole did not move past the 30-cm zone with most of the material remaining in the top 10 cm.

Laboratory studies of the degradation of propiconazole have shown that, although photochemical degradation of the compound will occur in water, the major route of degradation under aerobic conditions in soils and sediments or in natural waters in darkness, will be microbial. The initial half-lives (50% decline times) of propiconazole in these laboratory studies ranged from several weeks to a few months: some of the transformation products (in particular 1,2,4-triazole) formed during these experiments have half-lives in that same range. Under anaerobic conditions no microbial degradation was found. There is no definitive evidence concerning the rate of photochemical degradation of propiconazole in natural waters: the persistence of the parent compound and its major transformation products in such compartments is, therefore, unknown.

Studies of the dissipation of propiconazole in field plots on a silt loam soil confirm the laboratory finding that propiconazole itself remains in the upper layers of the soil. The question of possible leaching of the transformation product 1,2,4-triazole to greater depths is unresolved in the absence of both laboratory studies of its leaching potential and monitoring of its occurrence in the field. However, the behaviour of 1,2,4-triazole in extraction procedures for soil samples suggests that it would be strongly retained by soil under environmental conditions.

Propiconazole is formulated as an emulsifiable concentrate for spray application to the crop. There is, therefore, a potential for contamination of sensitive environments (wetlands, surface waters) by spray drift near treated areas. Since propiconazole will be retained by adsorption onto the surface soil on which it falls, it could be transported from a treated area on particulate matter in runoff water. The amount of propiconazole that reaches the soil surface will depend on the growth stage of the crop to which it is applied and on the weather (especially rainfall) in the period soon after application. In clear weather and with a well-developed stand most of the sprayed fungicide will be intercepted by the plants and will dissipate by evaporation or by absorption and metabolism in the plant. Early rainfall may sufficiently wash off the applied fungicide onto the soil so as to necessitate the recommended re-application.

Environmental Toxicology

Wild Birds. The acute toxicity of propiconazole to birds is low. The acute oral LD_{50} to five-day old Peking ducks was greater than 6000 mg/kg. The acute oral LD_{50} to adult Japanese quail was found to be 2223 mg/kg.

Exposure of birds through ingestion of contaminated food is unlikely to cause mortality. When fed levels in the diet of up to 1000 mg/kg for five days, no mortalities of five-day old Peking ducks occurred. Similarly, no mortality of adult Japanese quail occurred when fed 1000 mg/kg diet for five days.

Effects on avian reproduction are not expected. Studies on avian reproduction showed the no-effect levels to be high, at 300 mg/kg for the Mallard duck and 1000 mg/kg for the Bobwhite quail.

Field studies on birds have not been done. Given the low toxicity of propiconazole to birds, field studies on avian effects seem unwarranted.

Wild Mammals. No wild mammals were tested. Propiconazole was of low toxicity to the laboratory mammalian species tested. The acute oral LD_{50} values ranged from 1344 to 1517 mg/kg for mice, rats, and rabbits. Propiconazole also has low dermal toxicity to rats and rabbits, the acute dermal LD_{50}'s being 4000 mg/kg and >5010 mg/kg, respectively. This suggests that propiconazole is not embryotoxic or teratogenic to rats or rabbits.

Studies using ^{14}C-labelled propiconazole demonstrated that intragastrically-dosed rats can readily metabolize this compound. It was shown that 53% to 67% and 28% to 46% of the residues were excreted via the urine and feces, respectively. Only low levels of radioactivity were detected in body tissues at 144 hours after dosing. A similar pattern of excretion and accumulation was observed in lactating goats.

Wild mammals have the potential of being exposed dermally, through inhalation and orally (chronic dietary). When applied at field rates, it is not expected that wild mammals will be at risk due to exposure to propiconazole.

Amphibians and Reptiles. No data are available to evaluate the risk to amphibians and reptiles from the use of propiconazole.

Aquatic Invertebrates. Propiconazole is not acutely toxic to *Daphnia magna*: the 48-h EC_{50} (immobilization) of the technical material is 11.5 mg/L. The formulated product, Tilt 430 EC, has a higher level of toxicity than the technical material, the 48-h LC_{50} being 1.34 mg active ingredient/L. The metabolite, 1,2,4-triazole, is considerably less toxic than the parent compound, the acute 24-h EC_{50} being 900 mg/L.

When applied at field rates (125 g active ingredient/ha), propiconazole itself is not expected to be directly toxic to *Daphnia magna* either through acute or chronic exposure.

Terrestrial Invertebrates. Under the conditions tested, propiconazole does not appear to be toxic to terrestrial invertebrates. Following a seven-day exposure to foliage treated at four times the proposed label rate, four species of beneficial insects (*Anthocoris nemorum*, *Coccygonymus turionellae*, *Coccinella septempunctata*, and *Chrysopa carnea*) showed no observable deleterious effects.

Earthworms suffered no mortalities during exposure for 28 days to sandy loam soil containing 20 mg propiconazole/kg soil. The formulation tested, however, was WP 10 which is different from those proposed for use in Canada. In a study of exposure for 14 days to 1,2,4-triazole in an artificial soil substrate, the no effect level was 100 ppm. Bioaccumulation of propiconazole by the earthworm was not studied.

Test results from exposure of bees to technical propiconazole suggest that this compound is of low toxicity, but no data are available from similar studies for comparative purposes. When applied at field rates, propiconazole is not expected to be acutely toxic to terrestrial invertebrates.

Soil microbial systems. Judged on the basis of measurements of the production of carbon dioxide (CO_2) under laboratory conditions, propiconazole at concentrations ranging much above those relevant to field-use had no significant deleterious effects on soil microorganisms in two clay loam soils amended with alfalfa meal. Similar absences of significant effects were found in soils amended with either cellulose, protein, or starch.

There were no significant effects on the soil nitrification process as measured by the conversion of ammonium ion to nitrate, and at realistic concentrations of propiconazole in the upper 5 cm of soil, no effects were found on either the rate of nitrogen fixation by *Rhizobium trifolii* or root nodulation of white clover.

The transformation product 1,2,4-triazole caused no environmentally significant interference with mineralization (CO_2 production) in two soils amended with alfalfa meal.

Plants. The effects of technical propiconazole on the growth of four species of algae were tested, and propiconazole was found to be highly toxic. The 11-day EC_{10} for three species of algae and the nine-day EC_{10} for a fourth species (*Selenastrum capricornutum*) were:

26 µg/L for *Navicula seminulum* (a freshwater diatom);
18 µg/L for *Skeletonema costatum* (a marine diatom);
6.8 mg/L for *Anabaena flos-aquae* (a blue-green alga); and
0.72 mg/L for *Selenastrum capricornutum* (a freshwater green alga).

These results suggest that propiconazole is an extremely effective algicide. Data on the toxicity of the formulated product to algae are not available, but were requested early in 1985.

In the data submitted, differing experimental conditions make it difficult to compare the toxicity of the metabolite 1,2,4-triazole with that of the parent compound. In the one available study of the metabolite, algal growth inhibition was measured over 5 days only, and on a species whose sensitivity to propiconazole is unknown. The 5-day EC_{10} for *Scenedesmus subspicatus* was about 1 mg/L.

If a pond less than one metre in depth is directly oversprayed at the label rate of 125 g active ingredient/ha, an initial concentration of propiconazole greater than 12 µg/L could be expected in the pond water. The persistence of propiconazole in the water column is not known. In addition, the current label states that the compound should be reapplied if rainfall occurs within two hours of spraying. It is expected, therefore, that the use of propiconazole near aquatic systems could result in levels in the water that would adversely affect algal communities.

Only one study is available to evaluate the risk to aquatic vascular plants from the use of propiconazole. The 14-day EC_{50} to *Lemna gibba* was estimated to be 9 mg/L. Although it appears that aquatic macrophytes are less sensitive than algae to propiconazole, such an extrapolation is difficult to make on the basis of one species, whose sensitivity relative to other species is undefined. *Lemna* is also known to respond differently when exposed through a spray rather than through solution.

No data are available to evaluate the risk to terrestrial plants from the use of propiconazole. Data produced during company phytotoxicity screens were requested in January 1985, but no data have been received.

Wildlife Habitat Impact Assessment. Wetland areas are important habitats for several forms of wildlife. To maintain our wildlife resources, it is important that the integrity of wetland habitats be maintained. Wetland areas could potentially receive propiconazole through direct spray or drift. Direct spray of propiconazole at label rates is expected to affect algal communities deleteriously, but it is difficult to assess the long-term effects on various consumer levels, of a kill or species shift in the primary producer level. Protection of aquatic habitats from the risk presented by the use (and especially by aerial application) of propiconazole near surface waters requires that a buffer zone of 15-m be specified.

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